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RESEARCH PLAN FOR MONITORING WETLAND ECOSYSTEMS

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EXECUTIVE SUMMARY

RESEARCH PLAN FOR MONITORING WETLAND ECOSYSTEMS

THE ENVIRONMENTAL MONITORING AND ASSESSMENT PROGRAM

The Environmental Monitoring and Assessment Program (EMAP) was initiated in 1988 to provide improved information on the current status and long-term trends in the condition of the Nation's ecological resources. Seven broad resource categories have been defined within EMAP: near-coastal waters, the Great Lakes, inland surface waters, wetlands, forests, arid lands, and agroecosystems. In addition, seven coordination and integration functions have been established to assist the resource groups and ensure consistency: (1) monitoring design, (2) development of indicators of ecological condition, (3) landscape characterization, (4) quality assurance and quality control, (5) field sampling logistics, (6) information management, and (7) integration and assessment. This document describes the rationale, objectives, and primary elements of the EMAP-Wetlands program to assess the condition of the Nation's wetland resources. Separate research plans are being prepared for the other EMAP resource groups as well as for each of the coordination and integration functions. As an integrated multi-resource program, the success of EMAP, and EMAP-Wetlands, will depend on the close cooperation and coordination among these various program components.

OBJECTIVES OF EMAP-WETLANDS

The overall goal of EMAP-Wetlands is to provide a quantitative assessment of the current status and long-term trends in wetland condition on regional and national scales. The specific, long-term objectives of EMAP-Wetlands are as follows:

- Quantify the regional status of wetlands, by measuring indicators of ecological condition and also hydrology, pollution exposure, and other major factors known to influence or stress wetlands (e.g., climate, land use).
- Monitor changes through time, on a regional scale, in the condition of wetlands and in hydrology, pollution exposure, and other factors that influence or stress wetlands.
- Identify plausible causes for degraded or improved conditions, by evaluating associations between wetland condition and hydrology, pollution exposure, and other factors that affect wetland condition.
- Assess the effectiveness of drainage and pollution control actions and other environmental policies on a regional scale and nationally.
- Provide annual statistical summaries and periodic interpretive assessments of wetland status and trends.

In the short term, EMAP-Wetlands will provide standardized protocols for measuring and describing wetland condition, provide estimates of wetland condition in several regions, and develop formats for reporting program results. Trend detection will clearly require longer periods of data collection and evaluation, and therefore is an intermediate goal. Diagnostic analyses, to identify or eliminate plausible causes for degraded or improved wetland condition, is considered the long term goal of for EMAP-Wetlands.

EMAP-Wetlands, therefore, will be a **national-scale monitoring network** designed to provide **quantitative answers**, with **known levels of confidence**, to **policy-relevant questions**, such as

- o What is the current status, extent, and geographic distribution of our ecological resources?
- o What proportion of these wetlands are in good condition; how many are in relatively poor condition?
- o Are conditions improving or degrading over time? In what proportion of the wetland resource are conditions continuing to decline and at what rate?
- o What are the most likely causes of poor or degrading condition? Which stressors seem to be most important, adversely affecting the greatest numbers (or area) of wetlands in the United States?

In addition, the information provided by EMAP-Wetlands will aid in identifying those wetland classes, geographic areas, and environmental problems most in need of more detailed monitoring, research, or remediation.

The EMAP-Wetlands monitoring program is still in the design and planning stages. Many specific issues need to be resolved, and most elements require further testing and evaluation prior to implementation. The purpose of this document is to present an overview of the proposed approach, rationale, and expected outputs from EMAP-Wetlands. More detailed plans for each phase and component of the program will be prepared at a later date.

COORDINATION WITH OTHER MONITORING PROGRAMS

EMAP-Wetlands is being designed and funded by the U.S. Environmental Protection Agency's (EPA) Office of Research and Development (ORD). However, other offices and regions within EPA (e.g., Office of Wetlands Protection) and other federal agencies [e.g., the U.S. Fish and Wildlife Service (USFWS) and National Oceanic and Atmospheric Administration (NOAA)] have contributed to its development and will participate in the collection and use of EMAP data. This coordination avoids duplicative monitoring efforts, facilitates the exchange of data, and increases the expertise available for refining the program design and interpreting the monitoring results. EMAP is not intended as a substitute for other monitoring and research efforts, but instead will provide a framework for integrating existing and new data.

The most significant source of quantitative data on U.S. wetlands is the USFWS's National Wetlands Inventory (NWI). The NWI is mandated by Congress to report on the status and trends in wetland **acreage** every 10 years. Given EMAP's goal to monitor and report on the status and trends in wetland **condition**, including acreage, cooperation between the two networks is imperative. EPA and the USFWS have reached consensus on the following proposed delineation of roles:

- o The NWI will continue to be responsible for monitoring the status and trends in wetlands acreage and loss. Acreage statistics produced by EMAP-Wetlands will be used by USFWS, as appropriate, in their status and trends reports.
- o EMAP-Wetlands will monitor and report on wetland ecological condition, using a composite of landscape indices and field measurements.
- o Joint NWI-EMAP interpretive reports on both wetland extent and condition will be produced after the year 2005. Until that time, coordinated reports will be published by each agency to meet its own objectives.

Cooperative efforts are also planned with NOAA's Coastal Oceans Program (COP), to jointly map and monitor coastal wetlands.

EMAP'S HIERARCHIAL DESIGN

Ultimately, EMAP will involve four tiers, or types of activities related to monitoring and assessing ecological condition (Figure 1):

- **Tier 1** -- landscape characterization, to determine the distribution and extent (numbers and area) of ecological resources in the United States;

- **Tier 2** -- assessments of ecological condition and major stressors, based on both remote sensing and field sampling of a subset of the sites identified in Tier 1, to estimate the regional status and trends in condition of the Nation's ecological resources;

- **Tier 3** -- more intensive sampling at a smaller number of sites to focus on special subpopulations of concern or for more detailed diagnostic analyses; and

- **Tier 4** -- ecological research, to complement the monitoring data collected in Tiers 1-3.

This document describes plans only for Tiers 1 and 2 of the EMAP-Wetlands program. Explicit proposals for Tiers 3 and 4 will be developed during later stages of the EMAP-Wetlands planning process. All four tiers will be required, however, to fully achieve the long-term program objectives.

TIER 1 SAMPLING FRAME

To achieve the objectives outlined above, EMAP-Wetlands will use standardized sampling methods and an unbiased probability-based sampling design to monitor wetlands over broad geographic areas and for multiple decades. The outputs from this program will be for the **estimates of wetland condition** for the **regional wetland population** (i.e., all wetlands of interest, within a given region), not site-specific information.

The proposed design strategy is based on a **permanent national sampling framework** consisting of a systematic triangular point grid placed randomly over the conterminous United States (Figure 2); a similar array is available for Alaska and Hawaii. This grid identifies approximately 12,600 locations at which all ecological resources will be catalogued and classified. Using existing maps, aerial photography, and satellite imagery, the numbers, classes, and sizes of wetlands will be determined for the area included within a 40 km^2 hexagon centered on each grid point. These 40 km^2 hexagons (40-hexes) describe an area sample representing one-sixteenth of the area of the United States, and provide the basis for the Tier 1 estimates of wetland extent and distribution.

Completion of the Tier 1 landscape descriptions for wetlands will be a cooperative effort between the EMAP Landscape Characterization task group and the NWI. Thus, the protocols and criteria to be used for EMAP-Wetlands will be consistent with those applied for the NWI Status and Trends program. Initially, EMAP will rely on existing NWI maps to define the Tier 1 sample. Subsequent updates of the Tier 1 landscape descriptions will be conducted periodically, most likely at 10-year intervals.

The wetlands identified at Tier 1 will be classified into ecologically distinct wetland classes using aerial photography and based on vegetation cover, landscape attributes, flooding regimes, and the dominant water source. The proposed EMAP-Wetlands classification system was derived from the Cowardin wetland classification developed for the NWI. Subclasses of the full Cowardin system have been aggregated,

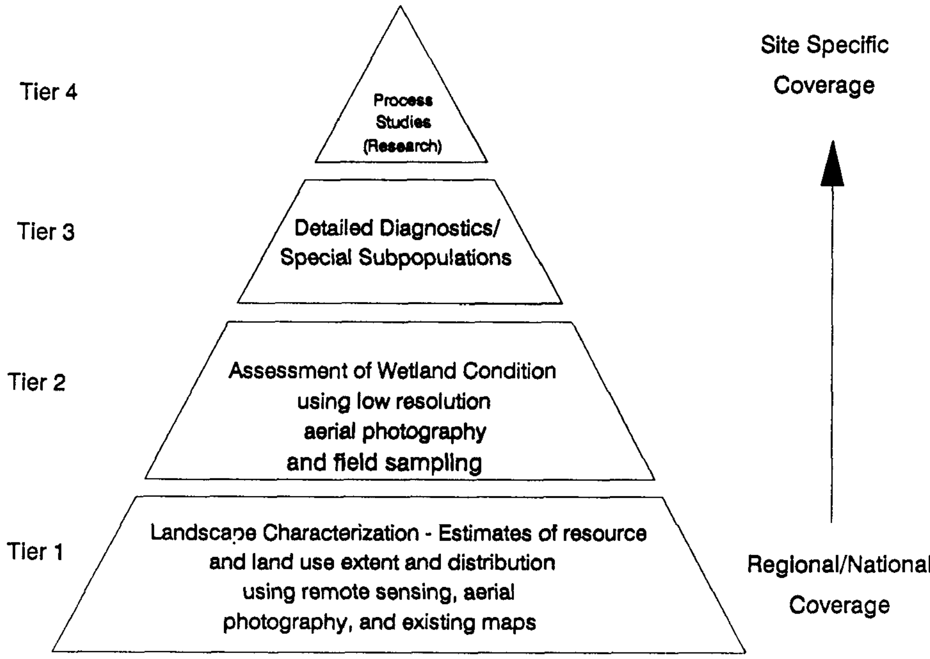

Figure 1. Concept of a four tiered design approach in EMAP. Most EMAP efforts will concentrate on Tiers 1 and 2.

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however, to group wetlands with similar characteristics and forcing functions. The explicit **Tier 1 target population** for EMAP-Wetlands consists, therefore, of all wetlands

- o included within the Cowardin classification system and belonging to one of the EMAP-Wetlands classes, and

- o identified as a wetland during the Tier 1 mapping process as implemented for the NWI (i.e., using primarily stereoscopic analyses of aerial photography).

Thus, vegetated wetlands, as defined for EMAP, do not represent all United States wetlands as delineated by the recent interagency wetland identification criteria (Federal Interagency Committee for Wetland Delineation 1989), primarily because of the limitations and errors associated with identifying and mapping wetlands using aerial photography rather than ground sampling. In particular, very small wetlands (generally < 0.5 ha) and those obscured by dense forest cover may not be visible on 1:40,000 aerial photographs used by NWI and, by definition, therefore are excluded from the EMAP-Wetlands target population. Wetlands, with insufficient vegetation cover (< 30%; see Section 3.3), would also not be included within EMAP-Wetlands. Periodic updating of the Tier 1 resource characterization (at approximately 10 year intervals) would, however,

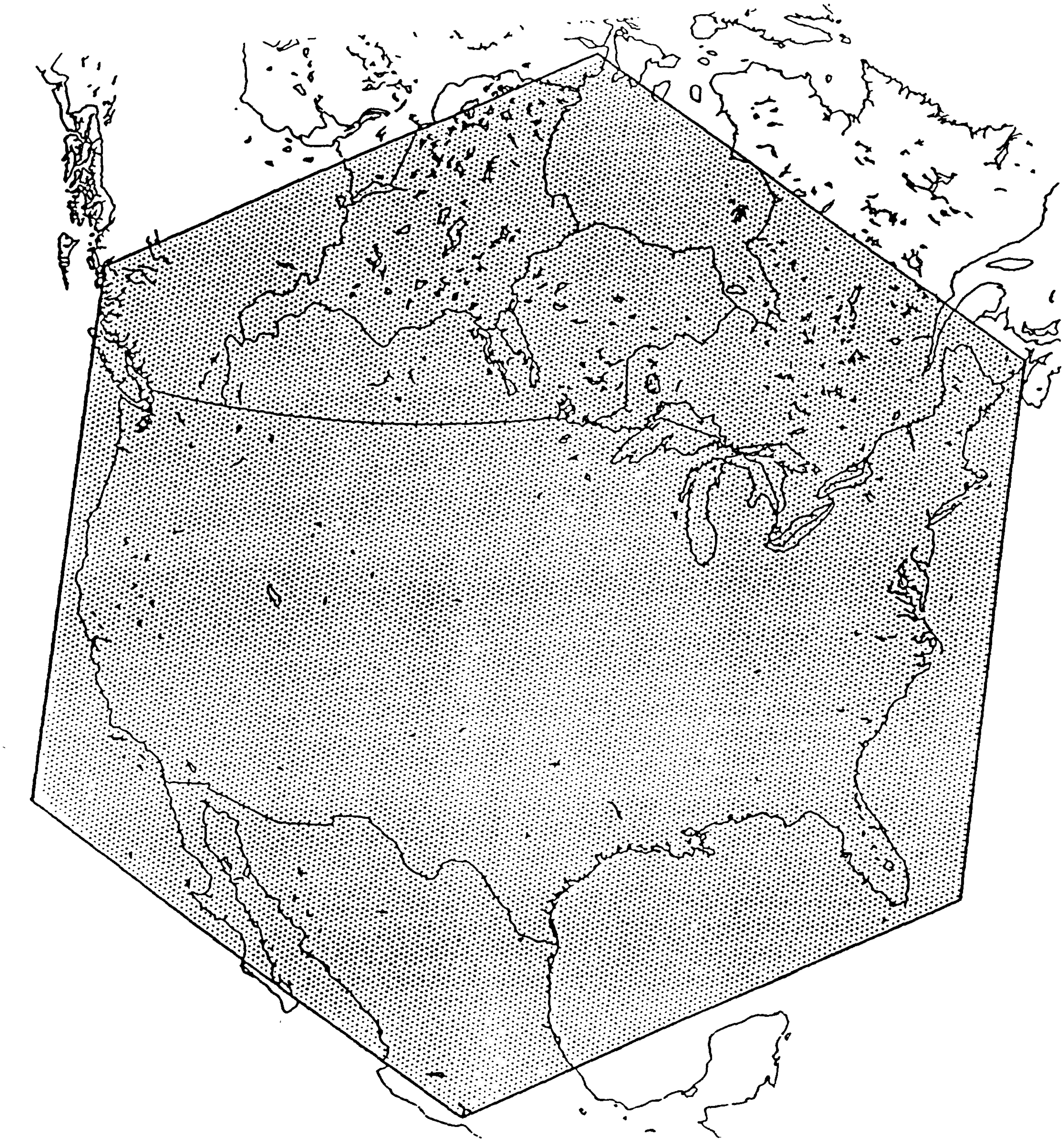

Figure 2. EMAP Tier 1 grid (not randomized) for North America. Spacing between points is about 27 km. (Overton et al. 1990).

add any newly constructed, natural, or mitigated, vegetated wetlands visible on the updated aerial photographs to the target population.

TIER 2 RESOURCE SAMPLING UNITS

The Tier 2 resource sample will be a subset of the Tier 1 sample (consisting of all wetlands within the 40-hexes), selected by probability methods and stratified as needed to ensure an adequate sample size for each wetland class and region of interest. Additional remote sensing analyses (e.g., using low altitude aerial photographs, < 1:6,000) and field visits to each Tier 2 site will permit data collection and the assessment of wetland condition. The outputs from Tier 2 provide the primary basis for quantifying the regional status and trends in wetland condition. Approximately 3200 wetlands will be sampled at Tier 2.

The optimal procedures for selecting the Tier 2 sampling units are still being investigated. However, the basic approach will be to (1) randomly select a subset of the 40-hexes in which wetlands of the class of interest occur and then (2) randomly select an individual wetland unit, in the wetland class of interest, from each of the selected 40-hexes. This approach will result in a spatially distributed Tier 2 sample, similar in pattern to the Tier 1 systematic triangular grid.

The number of wetlands sampled for each wetland class for each region will depend on (1) the precision goals for regional estimates of wetland condition and (2) the expected variability in the measured indicators of wetland condition. In most instances, 50-100 wetland units per wetland class and reporting region should result in adequate estimates of the regional distribution of wetland attributes (i.e., cumulative distribution functions), so that changes in the tails of the distribution can be detected and traditional population parameters (e.g., means, medians) can be calculated. It is anticipated that some landowners will deny access to sites selected for field sampling; in addition, some sites identified on maps may no longer exist. Thus, the number of sites selected at Tier 2 will exceed the number required to achieve the desired precision goals. All accessible Tier 2 sites will then be sampled. The results from Tier 2 will apply, therefore, only to "accessible" wetlands in the Tier 1 target population.

FLEXIBILITY OF THE EMAP DESIGN

An important characteristic of the EMAP design is its flexibility. The results from Tiers 1 and 2 can be summarized according to any subpopulation (e.g., wetland class) or spatial partitioning (e.g., region) of interest. The basic EMAP grid can be easily enhanced for greater sampling density in regions or for wetland classes of particular concern. The landscape characterization at Tier 1 provides a ready-made frame for sample selection, so that new or supplemental field programs can be implemented relatively quickly in response to new or emerging issues. Finally, the outputs from the EMAP-Wetlands monitoring network can be analyzed and expressed in a variety of ways, to address a diversity of policy-relevant questions. The EMAP design was selected, therefore, for its flexibility and adaptability, and to provide information on specific indicators measured during a specific index period, as a "snapshot" of the overall condition of a system.

TIER 2 SAMPLING

The EMAP objectives include both the description of current status and the detection of trends through time. These two monitoring objectives result in conflicting design objectives with regard to the optimal allocation of samples in time and space. The proposed EMAP interpenetrating design represents a compromise between these two objectives.

The Tier 2 sites will be sampled on a four-year cycle, that is, one-fourth of the sites in a region will be visited each year. By the fifth year, all sites will have been sampled and a second cycle will begin, using the same subsets of resource units. The sample sites are partitioned so that the basic systematic triangular grid (at one-fourth the density) is retained in each annual subsample, to maintain a nearly uniform spatial distribution of sites each year. Analyses of wetland status will be reported annually, as four year running averages over the four interpenetrating sample subsets. A few new sites will be added to the Tier 2 sample every year, and others dropped, to minimize any bias that might result from the knowledge of the EMAP-Wetlands monitoring network and thus the differential treatment of those sites.

Each Tier 2 site will be sampled, therefore, once, on a single day, every four years. In addition, field measurements will generally be conducted during a specific portion of the year, termed the index period. Ideally, the index period should be a time when most indicators are relatively stable. Sampling during the index period would then minimize the within-wetland indicator variability, resulting in more precise regional estimates of wetland status and improved ability to detect trends through time. Mid-growing season has been selected as the EMAP-Wetlands index period; the specific time of year for field sampling will be adjusted to account for regional and latitudinal differences in seasonal patterns.

INDICATORS OF WETLAND CONDITION

The term "indicator" has been adopted within EMAP to refer to the specific environmental characteristics to be measured or quantified through field sampling, remote sensing, or compiling of existing data. The selection of indicators is viewed as a multi-year process, now in its fairly early stages. The indicators proposed in this document are considered **research** indicators; each requires additional field testing and evaluation, and in some cases methods development, prior to full-scale implementation.

It is critical to the success of EMAP-Wetlands that the characteristics of the environment monitored are appropriate to the program's assessment goals. The first step in the indicator development process, therefore, is to define a framework for indicator interpretation, by identifying the environmental values, assessment endpoints, and major stressors of concern for the resource. The interpretation of the EMAP-Wetlands monitoring results will focus around three major assessment endpoints:

1. **Productivity**, including both floral and faunal components.

2. **Biodiversity**, defined by the variety of floral and faunal species inhabiting the wetland, in terms of both community composition and structure, as well as the functional niches that are represented.

3. **Sustainability**, defined as the robustness of the wetland; its resistance to changes in structure and function and persistence over long periods of time, as measured by both a wetland's size and hydrology.

Wetland condition will be judged, therefore, in relation to the productivity, biodiversity, and sustainability of the system as inferred from the measured EMAP indicators. The objective is **not** to maximize the wetland attribute, such as productivity, but to evaluate the measured indicator values relative to expected norms for a wetland of that type and region. Natural wetlands are not always highly productive (e.g., ombrotrophic bogs) nor highly diverse (e.g., coastal salt marshes). The proposed EMAP-Wetlands indicators, and their relationships to these assessment endpoints, are illustrated in Figure 3.

As a group, the set of indicators measured for EMAP-Wetlands must provide an adequate basis both to assess wetland condition and conduct the diagnostic analyses described below. Four types of indicators will be monitored: (1) **response indicators**, which provide a metric of biological condition (e.g., vegetation community composition); (2) **exposure indicators**, which assess the occurrence and magnitude of contact with a physical, chemical, or biological stressor (e.g., nutrient concentrations); (3) **habitat indicators**, which characterize the natural physical, chemical, or biological conditions necessary to support an organism, biological population, or community (e.g., wetland hydrology); and (4) **stressor indicators**, which quantify natural processes, environmental hazards, or management actions that result in changes in exposure or habitat (e.g., changes in land cover type).

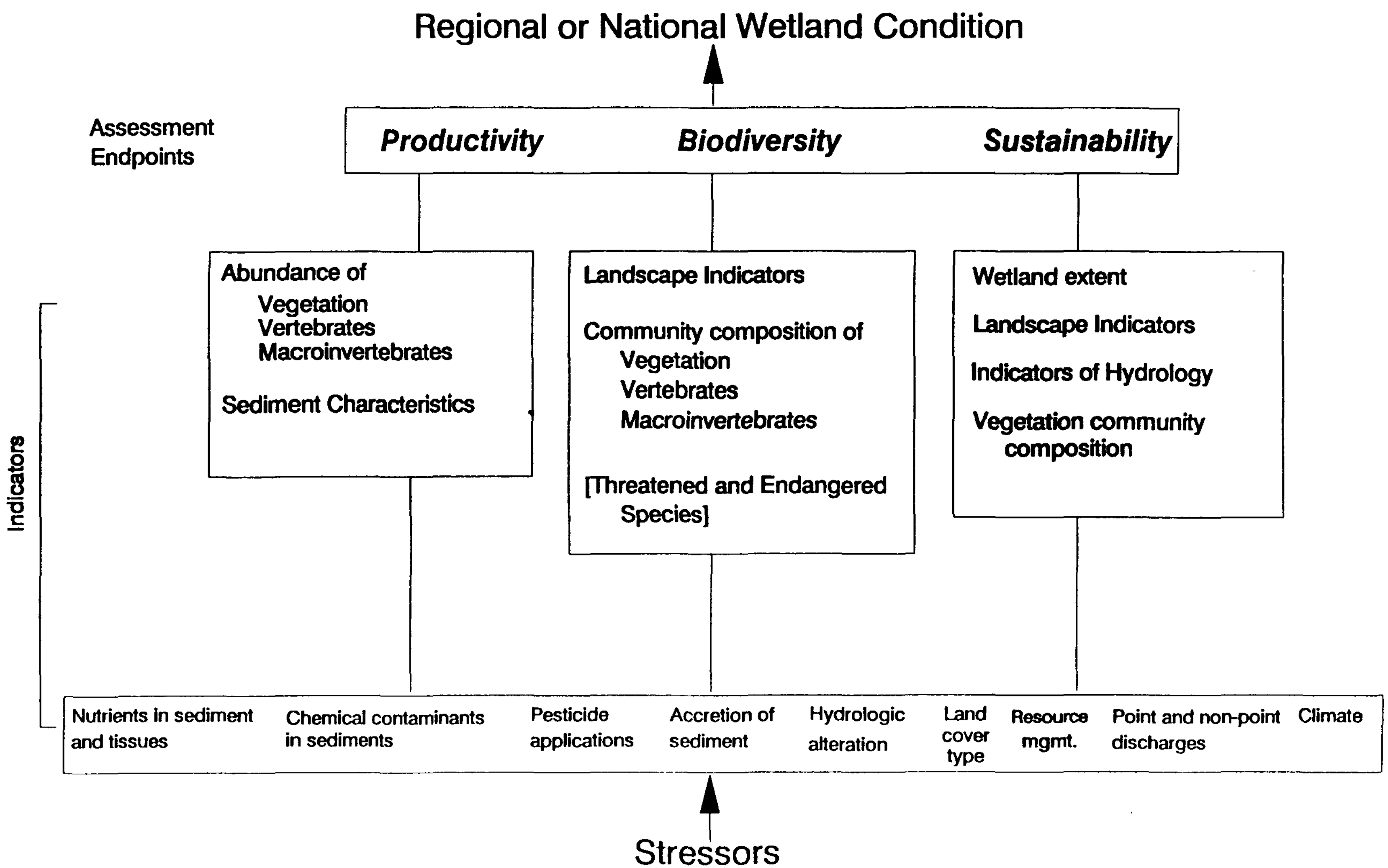

Figure 3. Conceptual framework for EMAP-Wetlands Indicator selection and Interpretation.

Indicator selection must be parsimonious, including only those indicators with a clearly defined role in evaluating wetland condition and sources of stress. At the same time, all important linkages and ecosystem components necessary to achieve the EMAP-Wetlands objectives must be represented. Finally, in selecting EMAP indicators, it is critical to remember both the temporal and spatial context in which the indicator will be used and interpreted -- to assess **long-term** trends at a **regional** scale (Figure 4). Thus, the selected indicators should also be integrative measurements (over both time and space) of wetland condition.

ASSESSING WETLAND HEALTH

The assessment of ecosystem condition or, by human analogy, "health" requires both (1) the occurrence of certain criteria considered indicative of a healthy sustainable resource and (2) the absence of known stressors and detectable symptoms of ecosystem stress. The challenge for EMAP-Wetlands is to conduct such an assessment using the types of information and measurements that can be collected within the constraints of the EMAP design. No indices of wetland condition currently exist that are widely accepted in the scientific literature and have been tested and applied on regional scales. The development of techniques for assessing wetland health will require, therefore, innovative approaches to data analysis and interpretation, and will be the subject of substantial future research within the EMAP-Wetlands program.

In general, for each wetland class in each region, wetland condition will be judged by comparing the measured indicator values with

- expected normal ranges for each response variable, derived from measurements at reference sites, historical records, the available literature, and (or) expert judgement; and

- information on stress-damage thresholds for each exposure indicator, obtained from the literature and available data.

Reference sites will be monitored for each wetland class and region, representing the least disturbed and most disturbed wetlands in the 1990 landscape. Generally, these sites will be off-grid, that is, "found" sites not part of the EMAP probability sample. Preferably, many will be part of existing monitoring or research programs with long-term records on wetland condition, which may be used to aid in the interpretation and validation of EMAP's "snapshot" sampling strategy. To the degree possible, the least disturbed sites will be "pristine" wetlands in protected areas, such as National Parks, in the U.S. Forest Service's Research Natural Areas, or part of the National Science Foundation's Long Term Ecological Research (LTER) program. Changes at these least disturbed sites will provide information on the influence of climatic fluctuations and natural succession on wetland condition and characteristics. Reference sites will be monitored for EMAP-Wetlands using the same protocols and procedures as for other Tier 2 sites, although reference sites will likely be sampled annually rather than every four years.

The terms nominal and subnominal have been adopted within EMAP to refer to "healthy" and "unhealthy" conditions, respectively. Wetlands classified as nominal are assumed, by definition, to be performing as expected for a wetland of that type, within that region, and for the specific assessment endpoint of interest. Classification of a wetland as nominal or subnominal will rely not on any single indicator, but on the full set of monitored response, exposure, habitat, and stressor indicators. Specific approaches for dealing with apparent inconsistencies in indicator signals, or for formally combining indicators into a joint index of wetland condition, will be explored as part of the EMAP-Wetlands indicator development process. Estimation of the numbers of nominal (deemed healthy and sustainable) and subnominal (unhealthy) wetlands in the United States (e.g., Figure 5) and trends through time in wetland health are an important assessment objective for the EMAP-Wetlands program.

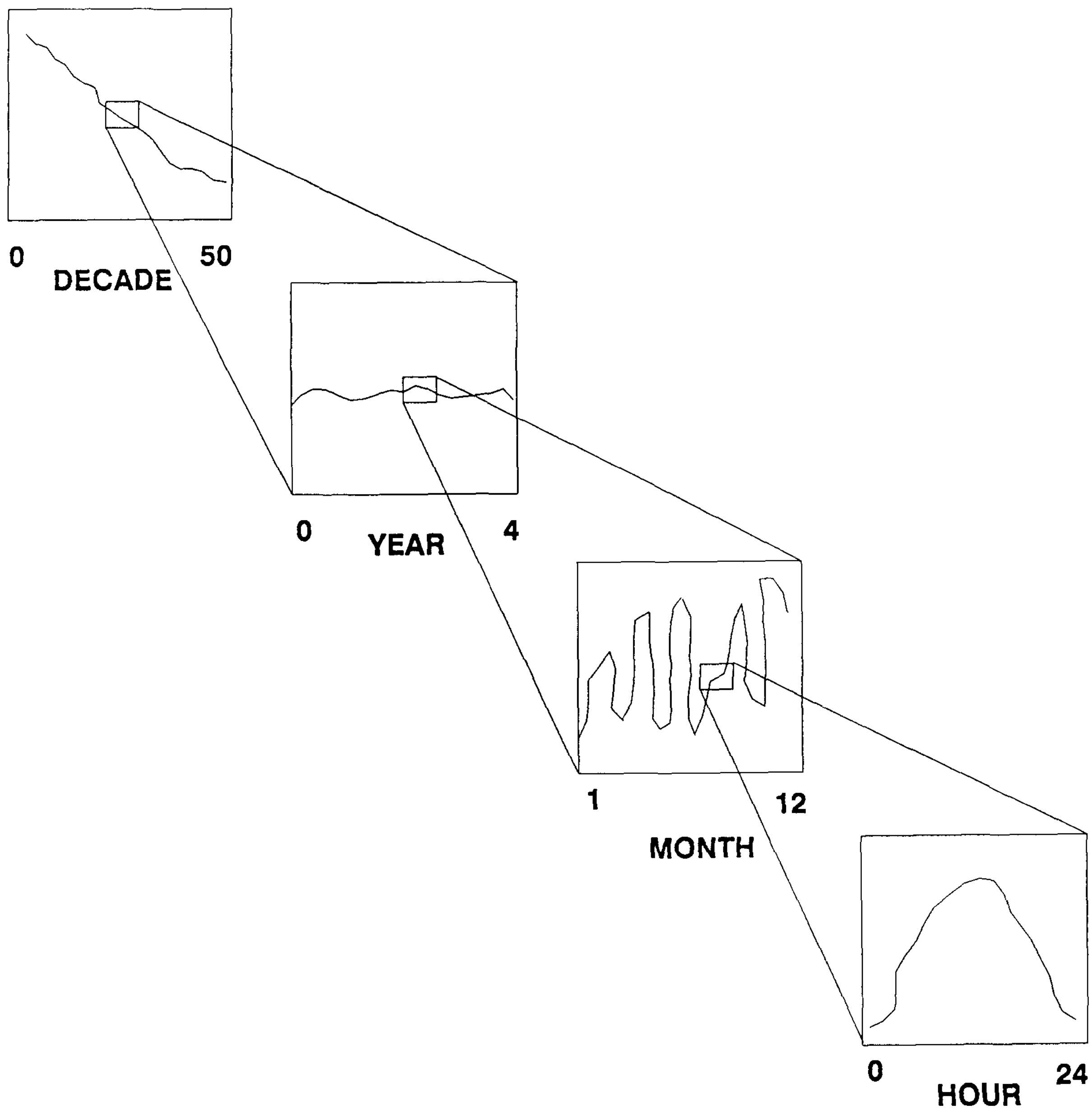

Figure 4. Scalar model of temporal changes in a hypothetical wetland indicator: long-term trends over decades, fluctuations over a one-year period, monthly variations, and daily fluctuations. Data collected for EMAP-Wetlands will be used to interpret long-term, regional trends and will be interpreted, therefore, within the temporal context illustrated in the upper leftmost box.

DIAGNOSTICS

A final major issue is the identification of plausible causes for observed regional patterns and changes in wetland status over time. The data collected by EMAP-Wetlands will be observational; thus, specific cause-and-effect relationships cannot be tested or proven. However, correlation analyses and simple diagnostics can be used to identify, on a regional scale, likely important causes of nominal and subnominal condition. Using the EMAP statistical design, the regional importance of each major stressor can then be estimated, as illustrated in Figure 5.

Natural sources of variability (e.g., climatic fluctuations, wetland succession) and resource management activities will also influence wetland condition. To the degree possible, these other external "stressors" will be accounted for in the analysis of wetland status, changes in wetland status over time, and plausible causes of degrading or improving conditions. Specific approaches for distinguishing between natural factors and anthropogenic stressors will be explored as part of the continuing EMAP-Wetlands planning efforts.

QUALITY ASSURANCE

The production and assurance of quality data must be an integral part of any program that intends to produce useful information. Consistent with this goal, and with EPA's policy to ensure that all environmental data are of known and documented quality, EMAP-Wetlands will include a comprehensive quality assurance and quality control program. Major elements of the program will include (1) developing and documenting standard operating procedures (e.g., methods manuals), (2) staff training, (3) maintaining suitable facilities and equipment, (4) the use of quality control samples to validate both the analytical data and the methods used to collect the data, (5) external audits, and (6) extensive data verification and validation checks on the data base management system. Finally, the development of data quality objectives (DQOs) will provide the framework for balancing the tradeoffs between the quality of data needed to make sound decisions and project constraints and costs.

REPORTING

To be of maximum use, data must be transformed into useful information as quickly as possible. Therefore, EMAP-Wetlands' goal is to produce annual statistical summaries of the monitoring results for the preceding year within nine months following the collection of the last field sample. These reports will provide summaries of response, exposure, and habitat indicators for the regions sampled, but with minimal interpretation. Interpretive reports will be published for the Congress, interested scientists, and decision makers every 5 years, after each sampling cycle. After 2005, these reports will be prepared jointly with the NWI. Special scientific reports and peer-reviewed papers also will be published periodically, to address particular topics of interest.

IMPLEMENTATION PHASES AND TIMETABLE

Several important design, indicator, and logistical issues need to be evaluated, field tested, and finalized before the EMAP-Wetlands program will be ready for full-scale implementation. Three types of research activities are planned: (1) analysis of existing data sets and simulation studies, (2) field pilot studies, and (3) regional demonstrations. Within a given region and wetland class, these proposed tasks will generally be completed in sequence.

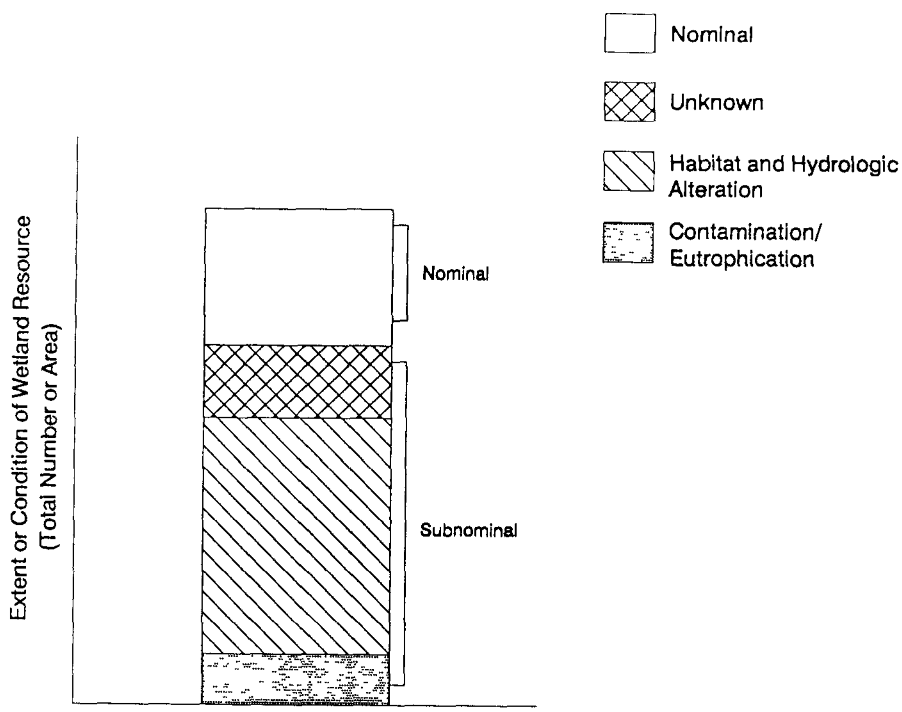

Figure 5. Results from a correlative approach to the initial partitioning of subnominal systems among plausible causes.

Analyses of existing data sets and simulation studies will be initiated in 1991. Data on wetland acreage and classes collected by the NWI will be used extensively to evaluate and refine the proposed EMAP-Wetlands sampling frame. Appropriate data sets for indicator development and evaluation also will be compiled and analyzed beginning in 1991 to (1) identify those indicators that most effectively define wetland condition, (2) evaluate indicator responsiveness to important wetland stressors, and (3) quantify indicator spatial and temporal variability.

Pilot studies are field projects conducted on one wetland type in one region, with a limited set of indicators, to address a specific set of questions related to the field sampling design and (or) wetland indicators. Regional demonstrations, on the other hand, are field projects conducted in a survey mode, using the EMAP-Wetlands sampling frame and protocols. Demonstration projects will be conducted for each wetland class and region; one-fourth of the Tier 2 sites in the wetland class and region will be sampled.

Figure 6 provides a schematic of the proposed strategy for field testing and implementing EMAP-Wetlands. The program begins by sampling one wetland class in one region, with a field pilot, followed by a regional demonstration project, and finally full-scale implementation for the region and wetland class. Using this same sequence of pilot, regional demonstration, and implementation, the monitoring network will gradually be scaled up by

1. monitoring the wetland class in additional regions, adding a new region each year until the wetland class is monitored nationally, and

2. adding new wetland classes yearly, starting in one region and gradually expanding to other areas.

In 1991, the first pilot study will be initiated in the coastal marshes of Louisiana, selected because of the intense interest in coastal land loss. Sampling of the Louisiana coastal area will be conducted cooperatively with the EMAP-Near Coastal resource group and the COP. In 1992, a second pilot study will be conducted in flooded emergent wetlands (prairie potholes) of the Midwest; in addition, field activities in Southeast salt marshes will be expanded to a regional demonstration project. Flooded emergents were selected as the second priority wetland class because of the high level of interest in these systems by EPA's Office of Wetlands Protection, the USFWS, the Nature Conservancy, and Ducks Unlimited. In 1993, plans call for a third pilot study of flooded forested wetlands (bottom hardwood wetlands) in the Southeast, an expansion of the emergent wetland pilot to a regional demonstration in the Midwest, and full-scale implementation for coastal marshes in the Southeast. Plans and priority wetland classes for subsequent years are identified in Figure 6. By 1997, each of the five priority wetland classes listed in Figure 6 will have progressed to full implementation in at least one region. The first EMAP-Wetlands interpretive report, describing the condition of coastal wetlands, is scheduled for completion in 1996.

CLASSES	REGIONS	1991	1992	1993	1994	1995
1. Salt Marsh	1. Southeast	PILOT →	DEMO →	IMPLEM →	→	→
	2. Mid Atlantic			DEMO →	IMPLEM →	→
	3. West Coast				DEMO →	IMPLEM
2. Flooded Emergents	1. Midwest (prairie potholes)		PILOT →	DEMO →	IMPLEM →	→
	2. Northeast				DEMO →	IMPLEM
3. Bottomland Hardwood	1. Southeast			PILOT →	DEMO →	IMPLEM
4. Saturated Emergents	1. Midwest (prairie potholes)				PILOT →	DEMO
5. Saturated Forested	1. Northeast					PILOT

Figure 6. Timeline and priority wetland classes and regions for EMAP-Wetlands field testing [pilot studies (PILOT) and regional demonstrations (DEMO)] and implementation (IMPLEM) through 1995.

1.0 INTRODUCTION

1.1 OVERVIEW OF EMAP

This document describes the rationale, approach, objectives, and strategy for establishing a long-term monitoring program to assess the status and trends in the ecological condition of the Nation's wetlands. The proposed program is one element of the Environmental Monitoring and Assessment Program (EMAP), a nationwide program administered by the U.S. Environmental Protection Agency's (EPA) Office of Research and Development (ORD). EMAP is designed to characterize the changing conditions of the Nation's ecological resources on large geographic scales over long periods of time. Although EMAP is designed and funded by ORD, other offices and regions within EPA (e.g., Office of Water) and other federal agencies (e.g., U.S. Fish and Wildlife Service) have contributed to its development and will participate in the collection and use of EMAP data.

In recent decades, the EPA, the U.S. Congress and many private environmental organizations have increasingly cited the need for national documentation of baseline environmental conditions against which changes might be compared over the long term. Affirming the existence of a gap in the environmental data upon which regulations are developed and based, the EPA Science Advisory Board recommended in 1988 that the EPA initiate a program to monitor the status and trends of the Nation's ecological resources, as well as develop innovative methods for anticipating emerging environmental problems before they reach crisis proportions. The proposed program would signify commitment to a long-term, regional- and national-scale effort to document, and periodically assess and report on the condition of ecological resources. EMAP is being developed to fulfill this mission.

The overall goal of EMAP is to monitor the condition of the Nation's ecological resources, to evaluate the success of current policies and programs, and to identify emerging problems before they become widespread or irreversible. In the interest of meeting this goal, EMAP will answer the following questions (U.S. Environmental Protection Agency 1990):

- What is the current status, extent, and geographic distribution of our ecological resources?
- What proportions of these resources are degrading or improving, where, and at what rate?
- What are the likely causes of degraded or improved conditions?
- Are adversely-affected ecosystems responding as expected to control and mitigation programs?

Seven broad resource categories have been defined within EMAP: near-coastal waters, Great Lakes, inland surface waters, wetlands, forests, arid lands, and agroecosystems. Research plans are currently being developed for each of these EMAP components. In addition, seven coordination and integration functions have been established to assist the resource groups and ensure consistency: (1) monitoring network design, (2) development and evaluation of indicators of ecological status, (3) landscape characterization, (4) quality assurance and quality control, (5) field sampling logistics, (6) information management, and (7) integration and assessment. EMAP-Wetlands, therefore, is only one element of a multifaceted program. Because wetlands are transitional between aquatic and terrestrial environments and are ubiquitous, a high degree of integration with the other resource groups will be essential. Further information on the EMAP objectives, approach, and rationale is provided in Appendix A.

1.2 OBJECTIVES OF EMAP-WETLANDS

The overall goal of EMAP-Wetlands is to provide a quantitative assessment of the current status and long-term trends in wetland condition on regional and national scales. The specific, long-term objectives of EMAP-Wetlands are as follows:

- Quantify the regional status of wetlands, by measuring indicators of ecological condition and also hydrology, pollution exposure, and other major factors known to influence or stress wetlands (e.g., changes in climate, land use).

- Monitor changes through time, on a regional scale, in the condition of wetlands and in hydrology, pollution exposure, and other factors that influence or stress wetlands.

- Identify plausible causes for degraded or improved conditions, by evaluating associations between wetland condition, hydrology, pollution exposure, and other factors that affect wetland condition.

- Assess the effectiveness of drainage and pollution control actions and other environmental policies on a regional scale and nationally.

- Provide annual statistical summaries and periodic interpretive assessments of wetland conditions and trends.

In the short term, EMAP-Wetlands will provide standardized protocols for measuring and describing wetland condition, provide estimates of wetland condition in several regions, and develop formats for reporting program results. Trend detection will clearly require longer periods of data collection and evaluation, and therefore is an intermediate goal. Diagnostic analyses, to identify or eliminate several plausible causes for degraded or improved wetland condition, is considered the long term goal of EMAP-Wetlands. Diagnostic information will eventually be useful to establish priorities and research directives for more intensive and site specific studies into cause and effect process and relationships.

EMAP-Wetlands will serve a wide spectrum of clients: decision makers at all levels of government who influence and establish wetlands policy (e.g., the EPA Administrator, Congress, the U.S. Executive Branch); program managers who require objective information to assign priorities for research and monitoring (e.g., EPA Regions, federal and state agencies), especially those directed toward protecting and enhancing wetland resources; policy analysts who require an objective basis for evaluating the effectiveness of the Nation's environmental policies for protecting and enhancing wetland resources; environmental interest groups which influence policy and require information on the state of our wetlands to establish priorities for protection efforts; and scientists who seek long-term and (or) regional data on wetland resources.

1.3 WETLAND VALUES AND ECOLOGICAL CONDITION

The variety of vernacular names given for wetlands (e.g., swamps, potholes, bogs, fens, pocosins) attest to the great diversity of wetland types. Wetlands are characterized and distinguished by different combinations of soil, hydrology, salinity, vegetation, and other factors. For this program, EMAP-Wetlands will adopt the definition of wetlands used by the U.S. Fish and Wildlife Service (Cowardin et al. 1979) to be consistent with the National Wetlands Inventory. In brief, this definition states that "wetlands are lands where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface".

Wetlands perform many functions that benefit society. The wetland habitat offers unique physical and biotic features not found in other ecosystem types. They are productive resources that support breeding, nesting, and feeding activities for many species of fish and wildlife. In addition to providing habitat for the numerous obligate wetland species, approximately 20% of the species listed as threatened or endangered depend upon wetland habitats during some part of their life cycle. Wetland productivity is often greater than that of surrounding ecosystems, and supports both internal trophic relationships and biomass export. Wetlands provide critical spawning and nursery habitat for commercially and recreationally important fish and shellfish, and serve as primary nesting, feeding, and resting habitat for many species of migrating waterfowl.

The hydrologic functions provided by wetlands include water storage, flood abatement, and groundwater recharge and discharge. As natural reservoirs, wetlands help to moderate flooding and have been shown to reduce flood peaks by as much as 80 percent (Novitzki 1979a). Wetlands can serve as areas of either groundwater discharge or infiltration; some systems vary seasonally depending on local hydrologic conditions.

Wetlands also contribute to water quality improvement through sedimentation, pollutant immobilization, and uptake of various pollutants and nutrients. Their organic substrates often act as water filters, immobilizing substances as they pass through, or come in contact with, wetland soils.

By providing recreational opportunities and serving as a source of commercial products, wetlands are important economic resources. Non-consumptive users of wetlands are attracted by their diversity of plant and animal life. The sporting industry is dependent on the continued productivity of wetlands for sport fishing, fur-bearer harvesting, and waterfowl hunting. Forested wetlands support timber production and coastal wetlands support the annual harvest of saltwater fish and shellfish. Furthermore, wetlands provide educational and research opportunities and some are historically significant.

Despite their many positive attributes, wetlands have been continually converted for other uses since colonial expansion in the 1800s. By 1975, efforts to alter wetlands had resulted in the loss of nearly half of the Nation's contiguous wetlands (Tiner 1984). Several states have witnessed the loss of greater than 90% of their pre-settlement wetland acreage. Of the original 215 million acres believed to have existed in the late 1700s in what is now the conterminous U.S., only 95 million acres remained as of 1987 (Feierabend and Zelazny 1988). The most recent estimates available (Frayer et al. 1983) indicate that wetland losses continue at a rate of between 300,000 and 400,000 acres per year.

Few of the remaining wetland acres exist in an undisturbed condition. Chemical, physical, and biological alterations continue to threaten wetland health. Despite protective legislation regulating activities that directly impair wetland quality, adjacent land use and the cumulative impacts of incremental wetland losses threaten the quality and function of remaining wetlands. Consequently, successes in preserving wetland acreage fall short of what is needed to effectively maintain wetland quality (Feierabend and Zelazny 1988). Although activities such as irrigation and reservoir construction may actually increase wetland acreage, these artificial wetlands may not provide all of the functions of natural wetlands (Kusler 1983). Furthermore, wetland management practices may alter wetlands to enhance some functions while impairing others (The Conservation Foundation 1988).

The major documented stressors associated with wetland loss or degradation include (1) hydrological alteration, (2) direct physical alteration, (3) toxic contaminant influx, and (4) nutrient loadings (Mitsch and Gosselink 1986, U.S. Environmental Protection Agency, 1988). Changes in land cover type, land management, and point and non-point discharges may contribute to increases or decreases in these wetland stressors. Global atmospheric change, acidic deposition, and the invasion of exotic or nuisance species also may adversely impact wetland condition. Global climate change has the potential to overshadow all other effects in the future.

The relative importance of these stressors on the wetland resource varies through time, by region, and by wetland type. For instance, land management practices vary considerably in different regions of the United

States and introduce different stressors. In the midwest, where row-crop agricultural practices dominate the landscape, wetlands which are not drained or filled are susceptible to inflow of pesticides and nutrients. In the west, on the other hand, where range lands predominate, livestock grazing, burning, and waterway diversions are the major threats to wetlands.

1.4 CURRENT APPROACHES FOR STATUS AND TRENDS ASSESSMENT

The most significant source of quantitative data on the status and trends of wetland acreage in the United States is the National Wetlands Inventory (NWI) of the U.S. Fish and Wildlife Service (USFWS), Department of Interior. The USFWS established the NWI to generate information on the extent of the Nation's wetlands (Tiner 1984). The program was designed to develop national statistics that would estimate, on the average, the total change in acreage of each wetland type within 10% of the actual value with a probability of 90%. National estimates of wetland distribution and acreage in the lower 48 states were reported for the period between 1950 and 1970 (Frayer et al. 1983); an updated study, through the mid-1980s, has been completed and is currently in the review process. The Emergency Wetlands Resources Act of 1986 requires that updated assessments of wetland extent be produced on a 10-year cycle, with reports due in 1990, 2000, 2010, etc. Recent increases in the NWI budget will also enable more frequent reporting (e.g., on a 5-year cycle with interim estimates as necessary) as well as enhancement of the national sampling grid to allow for more precise estimates in selected regions. It is anticipated that the NWI and EMAP programs will merge at some time in the future to monitor wetland acreage (see Section 2.4).

No national program exists to describe wetland ecological condition; the few programs that do assess wetland condition are designed to evaluate local problems or compliance with environmental legislation, or to answer very specific questions. Despite recommendations from the scientific community for intensive long-term studies, long-term wetlands data are available for only a few sites and a small number of wetland types (e.g., Davis and Brinson 1980, Murkin et al. 1984). Furthermore, standardization of measurement techniques among studies is lacking and quantitative data on wetland ecological condition have not been collected from statistically representative wetlands in any region of the country (Adamus and Brandt 1990).

1.5 CURRENT POLICY AND RECOMMENDATIONS

Since the early 1970s when recognition of wetlands as valuable resources was emerging, interest in wetland protection efforts has increased substantially. The shift in public attitude favoring wetlands protection has been translated at both the federal and state levels into laws and public policies (Mitsch and Gosselink 1986). A number of state and federal laws have been designed to protect the quality and extent of wetlands. The principal federal laws that regulate activities in wetlands are Sections 404 and 401 of the Clean Water Act and Section 10 of the River and Harbor Act; other federal laws include the National Environmental Policy Act, the Coastal Zone Management Act, and a provision of the 1985 Food Security Act known as "Swampbuster".

Although a variety of federal and state laws currently affect the use and protection of wetlands, the jurisdiction over wetlands resources is spread among several agencies (U.S. Army Corps of Engineers, EPA, USFWS, and National Marine Fisheries Service). No federal agency focuses on the regulation of wetlands as their primary purpose (Zinn and Copeland 1982). The lack of consistent goals and federal oversight, and the sharing of wetlands protection responsibilities among and within federal, state, and local governments, have contributed to the continued loss and degradation of wetlands (Goldman-Carter 1989).

Recognizing the need for assessing and improving wetland protection policy, the EPA recently requested that the Conservation Foundation convene the National Wetlands Policy Forum to discuss major policy concerns. The final report of the Forum emphasized the need for improved assessment of wetland ecological condition and trends (The Conservation Foundation 1988). The report stated that "The United States...needs much better information on the condition of its wetlands resources, the rate at which they are being altered, the types of alterations, and the causes of these alterations". The Forum report also recommended that the Nation adopt a goal to achieve no overall net loss of the remaining wetland base.

1.6 EMAP APPROACH

EMAP-Wetlands has a number of features that make it unique among monitoring programs. It is a

- o probability based sampling program designed to
- o measure indicators of ecological condition, and relate these to indicators of pollutant exposure and habitat condition which will
- o provide statistically unbiased estimates of status, trends and associations among indicators with quantifiable confidence limits
- o over regional and national scales
- o for long periods of years to decades.

The regional monitoring approach of EMAP is expected to improve our capability to detect emerging problems and to identify those wetland classes most in need of research, assessment, or remediation.

Environmental monitoring data are collected by the EPA to meet the requirements of a variety of regulatory programs and by many federal and state agencies to manage particular ecological resources. EMAP-Wetlands is not intended to replace these existing monitoring programs, but rather to provide a framework for integrating existing and new data and approaches into unified responses to meet the goals of EMAP. Interagency coordination is in place with the Department of Interior (USFWS) and is expected to include other agencies (e.g., Department of Agriculture), EPA Regions, universities, and other groups. This coordination avoids duplicative monitoring efforts, facilitates the exchange of existing data for use in refinement of monitoring networks, and increases the expertise available to quantify and understand the observed status and trends in wetlands.

1.7 CONTENT AND ORGANIZATION OF RESEARCH PLAN

This document is a research prospectus, intended to serve as a basis for discussion of goals and priorities among Agency personnel, the scientific community, and decision makers in order to reach a consensus about the rationale and overall approach. It will also serve as a vehicle to describe the knowledge and methodology needs, activities required to meet those needs, and some sense of priorities. It does not include specific proposals and work plans to accomplish specific products. These details will be provided in future documents.

The remaining chapters of this document are organized in the following manner:

- o Approach and Rationale (Chapter 2) provides an overview of all aspects of the EMAP-Wetlands program.
- o Monitoring Network Design (Chapter 3) describes the proposed monitoring network statistical design.

- Indicators of Wetland Condition (Chapter 4) discusses the strategy and criteria for selecting the specific variables to be measured (i.e., indicators of environmental quality), the indicators that are currently being considered, and the rationale for their selection.

- Field Sampling Design (Chapter 5) provides a brief description of the proposed field sampling approach.

- Data Analysis (Chapter 6) outlines the key questions to be addressed and associated data analysis approaches for summarizing and interpreting EMAP data.

- Logistics Approach (Chapter 7) identifies the major technical and operational issues to be addressed for program implementation.

- Quality Assurance (Chapter 8) explains the program that will be developed to ensure that the quality of the data collected is adequate to meet the objectives and needs of prospective users.

- Information Management (Chapter 9) describes the data management procedures to be used to ensure that data collected are provided to users quickly and efficiently, and also the project information management systems to be used to monitor the status of project activities.

- Coordination (Chapter 10) provides an overview of the ongoing efforts to coordinate EMAP-Wetlands with other related federal and state monitoring programs, and with the other EMAP resource groups.

- Expected Outputs (Chapter 11) summarizes the major documents that will be produced by EMAP-Wetlands.

- Future Research and Timelines (Chapter 12) summarizes the sequence and timing of activities to be completed over the next five years prior to program implementation.

- References (Chapter 13) lists references cited in the text.

- Appendix A presents a conceptual overview of EMAP.

- Appendix B provides definitions for the proposed EMAP-Wetlands classes.

2.0 APPROACH AND RATIONALE

The purpose of this section is to provide an overview of the major components of the proposed EMAP-Wetlands monitoring program. Approaches are outlined for both developing the program design and implementing the strategy on a national scale.

As discussed in the Introduction, the goal of EMAP-Wetlands is to evaluate and report on the status and trends in wetland quality on regional and national scales. In other words, we will be reporting on wetland condition on regional and national scales, and on the status and trends in wetland extent as an important indicator of wetland condition. This goal raises many challenging questions, which converge on two general themes:

Condition

- o How do we define and measure wetland condition or, by human analogy, the "health" of the wetland system?
- o What are the most appropriate methods for determining the proportion of the Nation's wetlands that are nominal (healthy) and subnominal (unhealthy)?
- o What data can EMAP collect to identify plausible causes of subnominal conditions?

Design

- o What is the most appropriate sampling frame for quantifying the status and trends in wetland condition on regional and national scales?
- o How do we coordinate the EMAP probability-based sampling strategy with the USFWS's NWI to collaborate in reporting on the status and trends in wetland extent?
- o How will we extrapolate from the sample data to regional and national estimates of wetland health?

Detailed answers to these questions are provided in Sections 3-12; the following subsections, however, introduce key concepts and summarize briefly the proposed EMAP-Wetlands monitoring design (Section 2.1), the selected indicators of wetland condition and rationale for their selection (Section 2.2), the proposed approach for statistically linking environmental stresses to ecological condition (diagnostics; Section 2.3), plans for integrating EMAP-Wetlands with the NWI and other EMAP resource groups (Section 2.4), plans for reporting EMAP results (Section 2.5), the proposed phased approach to program development and implementation (Section 2.6), and the major limitations of the proposed program (Section 2.7).

2.1 EMAP-WETLANDS DESIGN

EMAP will report on the status and trends in condition of all ecologically distinct wetland classes, on regional and national scales. To achieve this goal, the EMAP-Wetlands program plans to use standardized sampling methods and an unbiased probability-based sampling design to monitor wetlands over a period of decades. The outputs from this program will be regional population estimates of wetland extent and condition (i.e., for the set or group of wetlands of interest, as a whole, within a given region), not site specific information.

To achieve this end, EMAP-Wetlands is adopting the EMAP hierarchical sampling frame (Overton et al. 1990), which is briefly outlined below.

The EMAP design involves four tiers, or types of activities related to monitoring and assessing ecological condition (Figure 2-1):

- **Tier 1** -- landscape characterization, to determine resource distribution and extent;
- **Tier 2** -- assessments of ecological condition and major stressors at a subset of the sites identified in Tier 1, to estimate the regional status and trends in condition of the Nation's ecological resources;
- **Tier 3** -- more intensive sampling at a smaller number of sites for more detailed diagnostic analyses or sampling of special subpopulations of interest; and
- **Tier 4** -- ecological research, to complement the monitoring data collected in Tiers 1-3.

Tier 1 is the broadest level, with the greatest spatial coverage. Ecological resources in the United States will be sampled via a systematic triangular point grid superimposed on the conterminous U.S. (Figure 2-2); a similar array is available for Alaska and Hawaii. This grid identifies approximately 12,600 locations at which all ecological resources will be catalogued and classified. Using existing maps, aerial photography, and satellite imagery, the numbers, classes, and sizes of wetlands and the surrounding land use will be determined for the area included within a 40 km^2 hexagon centered on each grid point. These tasks are the responsibility of the Landscape Characterization group (Norton et al. 1990); activities specific to the EMAP-Wetlands network design are discussed further in Section 3.

The Tier 2 resource sample will be a subset of the Tier 1 sample (consisting of all wetlands within the 40 km^2 hexagons), selected by probability methods. Additional remote sensing (e.g., low altitude aerial photography) together with field visits to each Tier 2 site will permit data collection and the assessment of wetland condition. The outputs from Tier 2 provide the primary basis for quantifying the status and trends in wetland condition. Plans call for the selection of 3,200 wetland field sampling sites from the wetland resource distribution generated in Tier 1.

The specific objectives and approaches for Tiers 3 and 4 have not been finalized, but will involve a diversity of studies designed to supplement and complement the basic EMAP network established in Tiers 1 and 2. In general, fewer sites will be sampled more intensively, including higher resolution studies of trends and special subpopulations of interest and more detailed evaluations of causes of degrading environmental quality in Tier 3, and process-level research to complement EMAP monitoring in Tier 4. The Tier 3 sites sampled may be a subset of those monitored in Tier 2 or result from an enhancement of the EMAP grid, as described in Section 3.1. Tier 4 sites will often be off-grid, that is "found" sites not part of the EMAP probability sample. For Tier 4, EMAP will rely initially on existing research programs, such as the National Science Foundation's Long Term Ecological Research (LTER) sites. As EMAP proceeds, gaps in these existing Tier 4 networks will be identified and filled.

The remainder of this document focuses on Tiers 1 and 2. Explicit plans for Tiers 3 and 4 will be developed during later stages of the EMAP-Wetlands planning process. All four tiers are required, however, to achieve the long-term program objectives defined in Section 1.2. Thus, the utility and effectiveness of the proposed plans for Tiers 1 and 2 must be judged within the context of this overall four-tiered approach to assessing the regional status and trends in wetland condition.

An important characteristic of the EMAP design is its flexibility. The results from Tiers 1 and 2 can be summarized according to any subpopulation (e.g., wetland class) or spatial partitioning (e.g., region) of

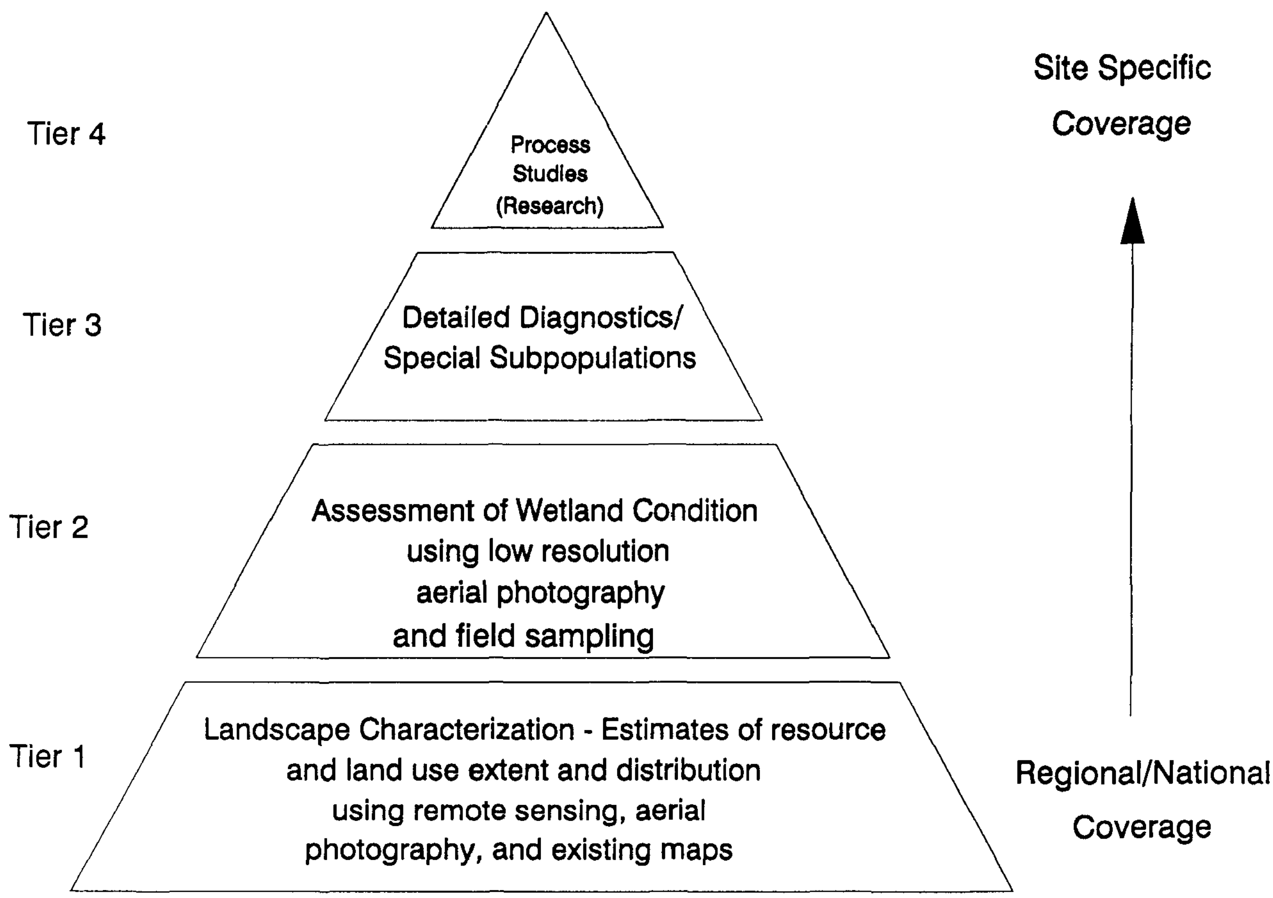

Figure 2-1. Concept of a four tiered design approach in EMAP. Most EMAP efforts will concentrate on Tiers 1 and 2.

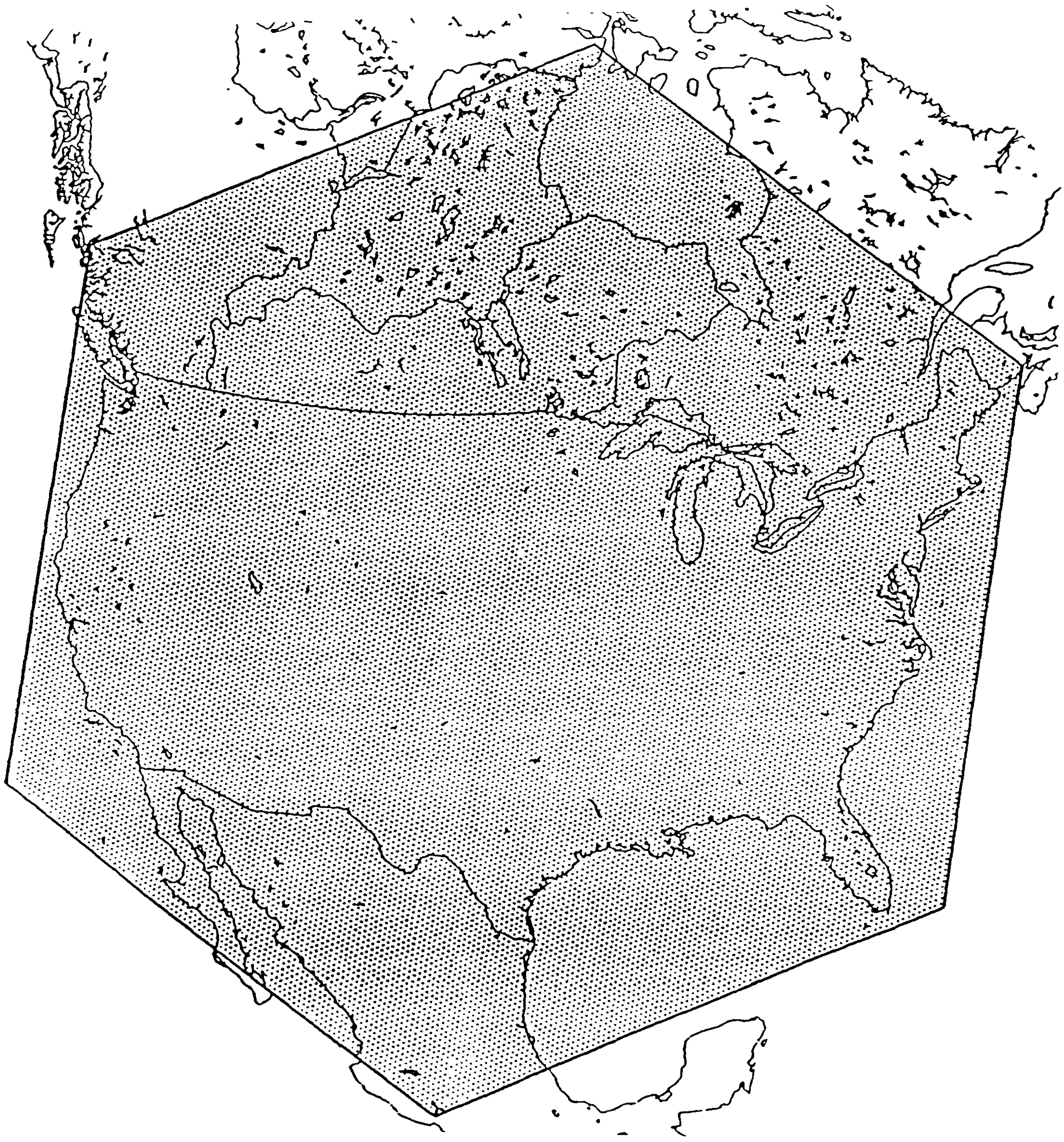

Figure 2-2. EMAP Tier 1 grid (not randomized) for North America. Spacing between points is about 27 km. (Overton et al. 1990).

interest. The basic EMAP grid density can be easily enhanced for greater sampling intensity in regions or for wetland classes of particular concern. The existence of the landscape characterization at Tier 1 provides a ready-made frame for sample selection, so that a field program can be mounted with minimal preparation, allowing for a relatively rapid response to new or emerging issues. Finally, the design, as well as the indicator strategy described in Sections 2.2 and 4, are appropriate for answering a variety of policy-relevant questions (see Section 6). The EMAP design has been selected, therefore, for its flexibility and adaptability, and to provide information on specific indicators measured during a specific index period, as a snapshot of the overall condition of the system.

The wetlands identified in Tier 1 will be classified into ecologically distinct wetland classes using existing technology (e.g., aerial photography) based on vegetation cover type, landscape attributes, flooding regimes, and dominant water source (i.e., proximity to lakes or streams, see Section 3.3). The proposed EMAP-Wetlands classification scheme was derived from the Cowardin classification system (Cowardin et al. 1979) developed for the NWI. Subclasses of the full Cowardin system have been aggregated, however, to group wetlands with similar characteristics and functions to facilitate assessments of wetland "health." Estimates of the regional status and trends in wetland condition will be calculated for each EMAP wetland class. The Tier 1 wetlands will be pre-stratified as needed during selection of the Tier 2 sample to ensure an adequate sample size for each wetland class and region of interest to achieve the desired precision goals for regional population estimates.

As noted above, the results from the Tier 1 and Tier 2 assessments of the status and trends in wetland acreage and condition also can be reported on multiple spatial scales and for different regional configurations, as long as an adequate sample size is maintained for the smallest spatial unit considered. During data analysis, wetlands will be partitioned into regions with similar ecological and stress characteristics. Initially, analyses of wetland condition will be conducted using the wetlands regionalization scheme proposed by Winter (U.S. Geological Survey, Denver, CO; in preparation), based on physiography and climate (Table 2-1). Other regionalization approaches (e.g., Omernik 1987; Bailey 1976, 1978; Hamond 1970; and Office of Technology Assessment 1984) will also be explored. EMAP results will be reported by political boundaries; for example, for distinct or aggregated EPA Regions (Figure 2-3).

The Tier 2 sites will be sampled on a four-year cycle; that is, one-fourth of the sites in a region will be visited each year. By the fifth year, all sites will have been sampled and a second cycle will begin. Spatially interpenetrating subsamples are used to maintain nearly uniform spatial coverage for each annual subsample. The results from EMAP assessments of wetland status will be reported as four-year average values, to accommodate this sampling pattern and to reduce the influence of annual climatic variations.

EMAP sampling will be limited to a confined portion of the year, an index period, in which the measured parameters are present and preferably representative of yearly conditions, and the parameter variability is either representative or at its minimum. Mid-growing season has been selected as the wetland sampling index period. During this time period, many proposed indicators [e.g. vegetation composition and abundance and soil characteristics (organic matter, accretion rates, and contaminant concentrations)] are present and representative of the year's hydrologic, chemical, and physical regimes. The specific index period will be adapted as needed to account for (1) regional and latitudinal changes in indicator attributes and (2) special case studies at a select number of sites.

The EMAP probability-based network design imposes constraints on several other aspects of the wetland monitoring and assessment effort. For example, the indicators of wetland condition selected for EMAP (Sections 2.2 and 4) must be meaningful when surveyed once per year during the proposed index period. In addition, the identification of plausible causes for observed subnominal conditions (Section 2.3) can only be conducted at a regional and national scale. Site-specific assessments of environmental problems will not be possible.

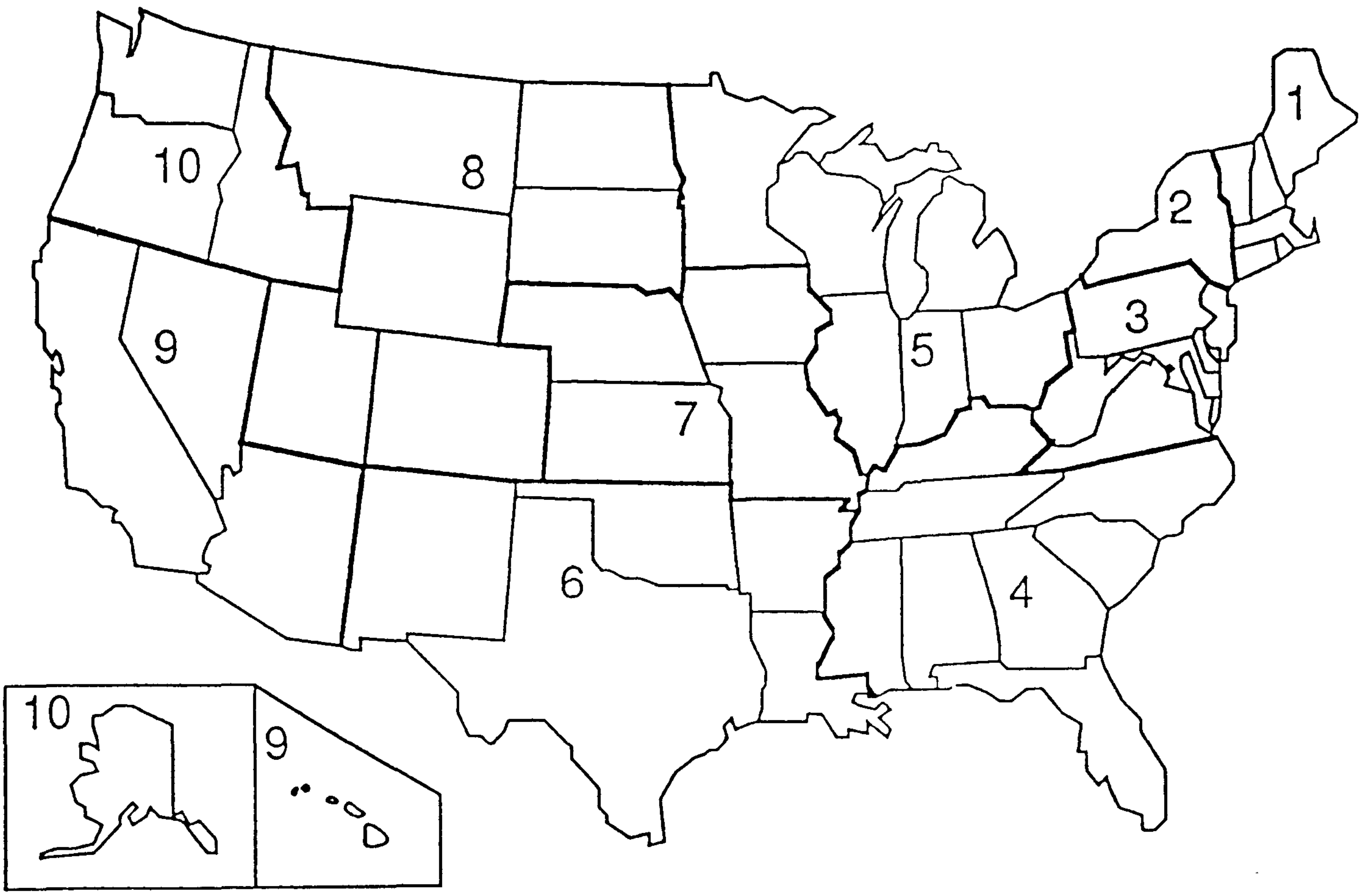

Figure 2-3. U.S. EPA Regions

Table 2-1. Proposed Wetland Regionalization Scheme, Defined by Both Physiography and Climate (Source: Winter, in preparation). The Eight Physiographic Settings, When Combined with Climate and Moisture Modifiers, Will Result in 23 Regions Within Which the Majority of U.S. Wetlands Occur.

Eight Principal Physiographic Settings

1. Terraces and scarps within coastal lowlands, including tidal flats
2. Riverine valleys, including the contiguous upland and river
3. Steep slopes with contiguous narrow lowlands
4. Large depressions with contiguous extensive flats
5. Morainal kettles
6. Dune fields
7. Sink holes and other depressions
8. Permafrost

Subdivided by Major Climatic Zones, based on gradients in

- o Temperature: cold to warm climates
- o Moisture: wet to dry climates

2.2 ASSESSING WETLAND CONDITION

Ecosystem health is defined in the historical literature as both the occurrence of certain characteristics or indicators that are deemed to be present in a healthy sustainable resource and the absence of known stressors or problems affecting the resource. More specifically, evaluating ecosystem health or condition involves a combination of the following approaches: (1) identification of systematic indicators of ecosystem functional and structural integrity, (2) measurement of ecological sustainability, and (3) an absence of detectable symptoms of ecosystem disease or stress (Rapport 1989). The challenge for EMAP-Wetlands is to conduct such an assessment using the types of information and measurements that can be collected within the EMAP monitoring design.

The term indicator has been adopted within EMAP to refer to the specific environmental characteristics to be measured or quantified through field sampling, remote sensing, or compiling existing data. Four types of indicators are recognized (although some indicators may serve multiple roles):

- o <u>Response indicator</u>: a characteristic of the environment measured to provide evidence of the biological condition of a resource at the organism, population, community, or ecosystem process level of organization (e.g., vegetation community composition).

- o <u>Exposure indicator</u>: a characteristic of the environment measured to provide evidence of the occurrence or magnitude of contact with a physical, chemical, or biological stressor (e.g., nutrient concentrations).

- o **Habitat indicator**: a physical, chemical, or biological attribute measured to characterize the conditions necessary to support an organism, population, or community (e.g., wetland hydrology).

- o **Stressor indicator**: a characteristic measured to quantify a natural process, an environmental hazard, or a management action that effects changes in exposure and habitat (e.g., land use). Stressor indicators differ somewhat from other indicator types in that they are often not measured on the EMAP sampling frame.

As a group, the set of indicators measured for EMAP-Wetlands must provide an adequate basis to both assess wetland condition and conduct the diagnostic analyses described in Section 2.3. Indicator selection must be parsimonious, including only those indicators with a clearly defined role in evaluating ecosystem health or sources of stress. At the same time, all important linkages and ecosystem components necessary to achieve these objectives must be represented. Finally, in selecting EMAP indicators, it is critical to remember both the temporal and spatial context in which the indicator data will be used and interpreted -- to assess **long-term** trends at a **regional** scale (Figure 2-4). Thus, the selected indicators should also be integrative measurements (over both time and space) of wetland condition.

The selection of indicators for the EMAP monitoring network is viewed as a multi-year process, requiring extensive testing and evaluation of each indicator prior to its full-scale implementation. To facilitate this process, a framework for indicator development and specific steps in the process have been defined (see Section 4). The indicators proposed in this document are considered **research indicators**. Together, they provide a balanced index of wetland condition, covering the major components and linkages within a wetland ecosystem, yet each requires additional field testing and evaluation, and in some cases methods development, prior to implementation.

Interpretation of the indicator measurements will focus around three major assessment endpoints:

1. **Productivity**, including both floral (i.e., vegetation growth rates for each layer of vegetation in the wetland) and faunal components (e.g., waterfowl productivity). Vegetation abundance and biomass can be measured directly. Fish and wildlife productivity, on the other hand, must be inferred from other measured wetland attributes, considered indicative of the potential for a wetland to support productive faunal communities or surrogates for fish and wildlife productivity.

2. **Biodiversity**, defined by the variety of floral and faunal species existing on the wetland, in terms of both community composition and structure, as well as the functional niches that are represented.

3. **Sustainability**, defined as the robustness of the wetland; its resistance to changes in structure and function and persistence over long periods of time, as measured by both a wetland's size and hydrology.

These endpoints were selected to reflect the major social and biological values associated with natural wetlands. Wetland condition will be judged, therefore, in relation to the productivity, biodiversity, and sustainability of the system as inferred from the measured EMAP indicators. The objective is **not** to maximize the wetland attribute, such as productivity, but to evaluate the measured indicator values relative to expected norms. Natural wetlands are not always highly productive (e.g., ombrotrophic bogs) nor highly diverse (e.g., coastal salt marshes).

The proposed EMAP-Wetlands indicators and their relationships to the assessment endpoints are illustrated in Figure 2-5. It is anticipated that this figure and indicator list will be refined, improved, and expanded as EMAP indicator research proceeds, as new methods are proposed by the scientific community based on advances in our understanding of wetland processes, and as we gain experience with the use and

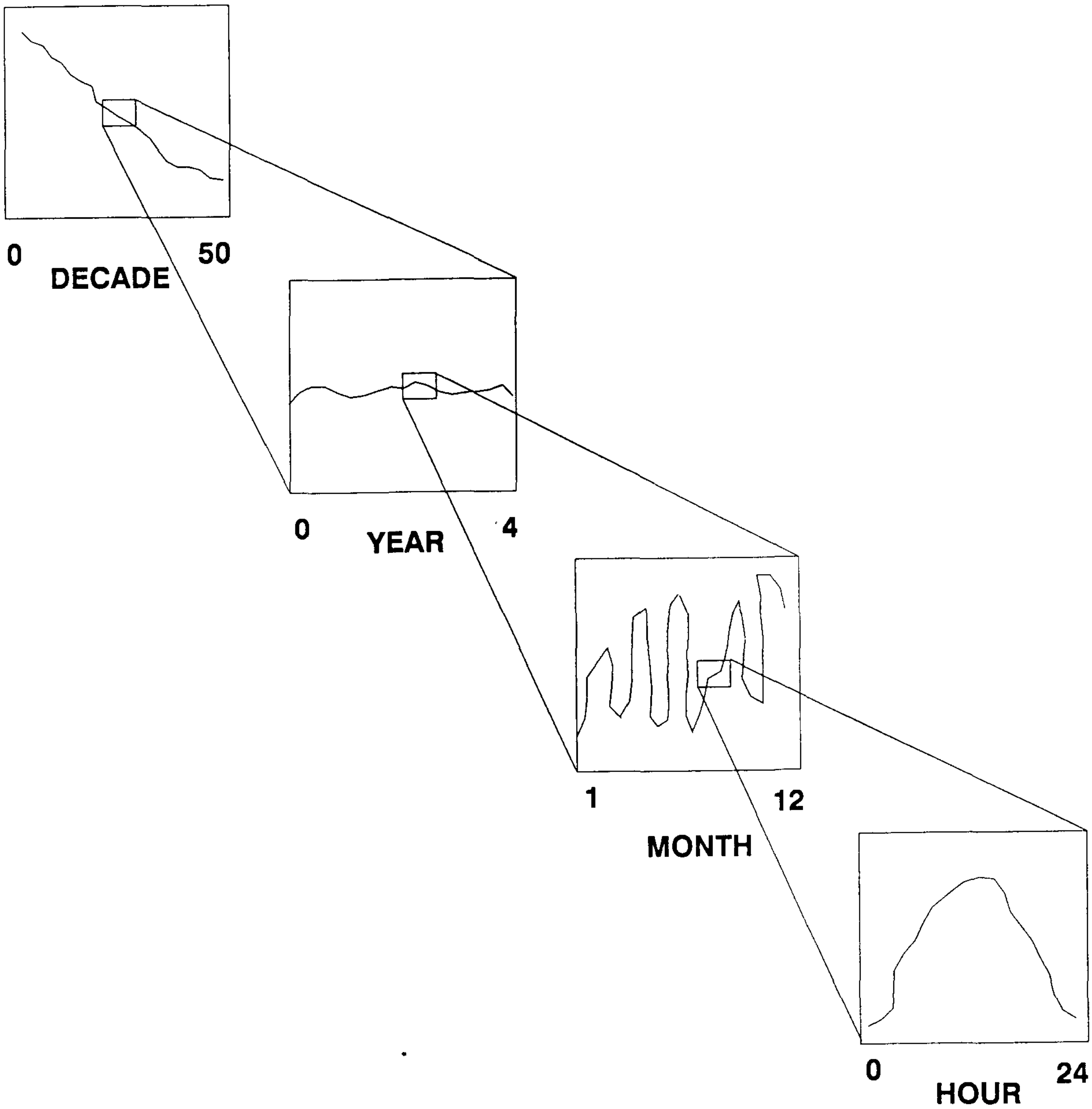

Figure 2-4. Scalar model of temporal changes in a hypothetical wetland indicator: long-term trends over decades, fluctuations over a one-year period, monthly variations, and daily fluctuations. Data collected for EMAP-Wetlands will be used to interpret long-term, regional trends and will be interpreted, therefore, within the temporal context illustrated in the upper leftmost box.

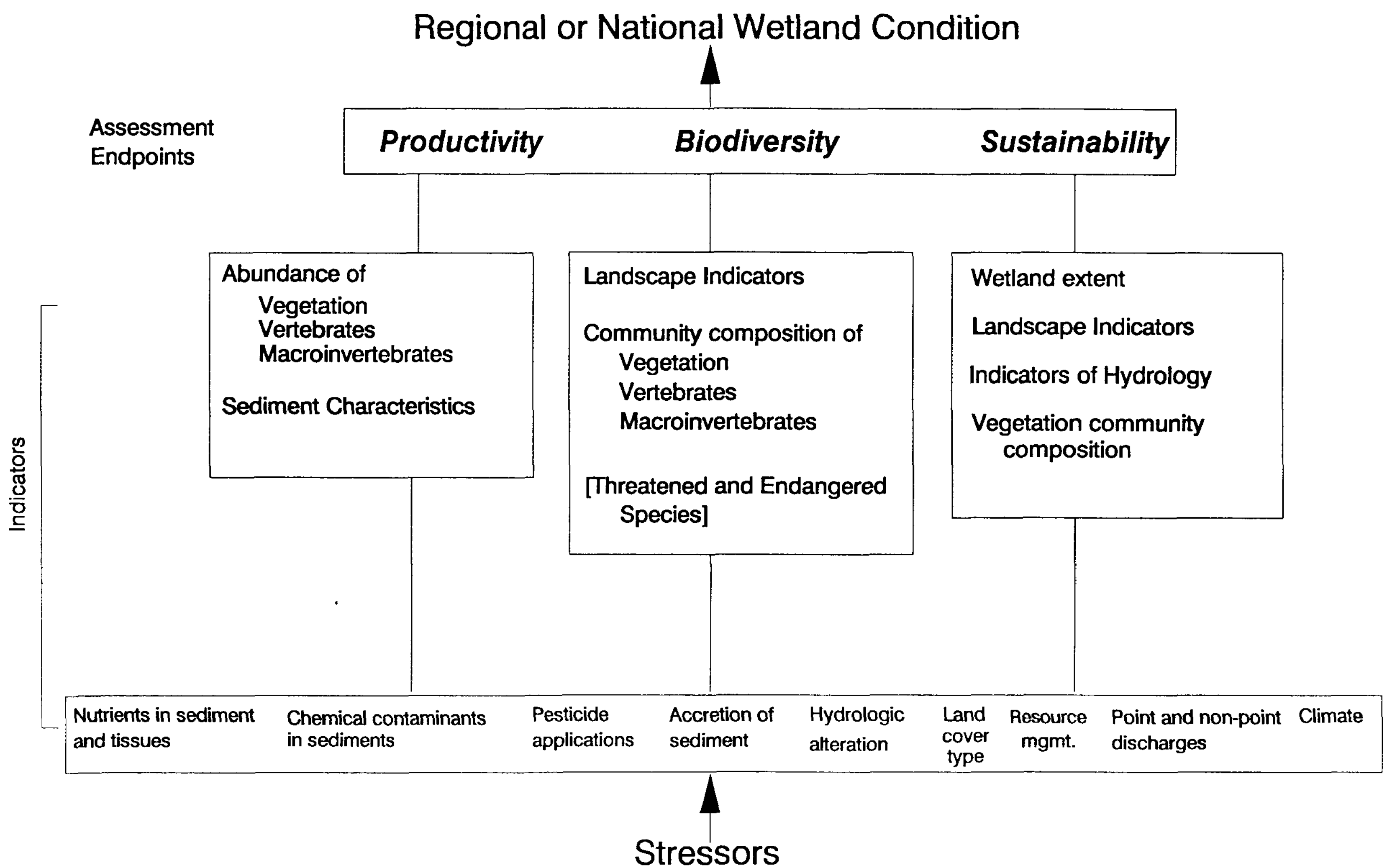

Figure 2-5. Conceptual framework for EMAP-Wetlands indicator selection and interpretation.

interpretation of indicators in EMAP. Further details on each indicator are provided in Section 4; Section 6 provides additional discussion on indicator interpretation relative to the selected assessment endpoints.

A second major task in assessing wetland condition is to determine specific values for each indicator that suggests the system is in good or acceptable condition. In EMAP, to avoid the semantic problems that could arise from using words such as good or acceptable, the terms nominal and subnominal have been adopted to refer to healthy and unhealthy conditions, respectively. Wetlands classified as nominal are assumed, by definition, to be performing as "expected" for a wetland of that type, within that region, and for the specific assessment endpoint of interest.

Evaluating wetland health is clearly a difficult task, and the procedures to be used are still being developed. In general, for each wetland class in each region, the condition of the wetland will be judged by comparing the measured indicator values with:

- expected normal ranges for each response indicator, derived from measurements at reference sites, available historical data, and information in the literature; and

- information on stress-damage thresholds for each exposure indicator, obtained from the literature and available data. In some cases, ecotoxicology tests may be needed to verify these damage thresholds.

Assessment of a wetland as either nominal or subnominal will rely not on any single indicator, but on the full set of monitored response, exposure, habitat, and stressor indicators. Specific approaches for dealing with apparent inconsistencies in indicator signals, or for formally combining indicators into a joint index of wetland condition, will be explored as part of the EMAP indicator development process (see Section 6).

Reference sites will be an important source of information on indicator levels and variations in wetlands with known levels of anthropogenic stress; they provide benchmarks for indicator interpretation. Within each wetland class in each region, a set of reference sites will be selected to represent the least disturbed and most disturbed wetlands in the 1990 landscape. In general, these sites will be off-grid. Preferably, many will be part of existing monitoring or research programs, with long-term records on wetland condition and stressors. To the degree possible, the least disturbed sites will be "pristine" wetlands in protected environments, for example in National Parks, in U.S. Forest Service Research Natural Areas, or included within the National Science Foundation's LTER program. Nominal reference wetlands will be selected within landscapes with minimal known anthropogenic disturbance, such that external stressors and anthropogenic factors would be expected to have minimal influence on the measured wetland attributes. Procedures for selecting both the least and most disturbed reference wetlands may be based on land use stratification techniques, such as the landscape development index (Brown et al., submitted); however, the specific techniques to be used have not yet been determined. The protocols for monitoring reference wetlands will be identical to those used for the EMAP-Wetlands Tier 2 sites, although reference sites will likely be sampled annually rather than every four years.

EPA-Wetlands will report on the proportion of the Nation's wetlands that are nominal (deemed healthy and sustainable) and subnominal (unhealthy). These data will be a critical tool with which EPA and Congress can assess and influence current wetland management decisions and policy. They can also be used to evaluate the success of the "no net loss" program and proposed water quality criteria for wetlands. Ultimately, EMAP-Wetlands data could be used by state and federal managers to both (1) establish "designated use" classes for wetlands and (2) identify sensitive wetland classes that need special regulatory consideration to be preserved with "no net loss".

2.3 DIAGNOSTICS

In addition to knowing the number and proportion of wetlands that are subnominal, it is also desirable to know what exposure, habitat, and stressor indicators are correlated with this subnominal condition. The EMAP monitoring data will be used to examine the statistical association, on a regional scale, between the occurrence of subnominal conditions and possible causes of these conditions, as inferred from the measured habitat and exposure indicators, as well as available information on external stressors [land use (e.g., percent agriculture, population density), pesticide application rates, and point and non-point discharges]. While these correlative analyses cannot prove causality, this eco-epidemiological approach will be used to narrow the range of plausible causes for observed regional patterns of wetland status and trends. Using the EMAP statistical design, the regional importance of each major stressor can then be estimated, as illustrated in Figure 2-6.

Natural sources of variability (e.g., climatic fluctuation, natural succession) and resource management activities are also likely to influence wetland condition. To the degree possible, these other external "stressors" will be accounted for in the analyses of wetland status, changes in wetland status over time, and plausible causes of degrading or improving conditions. Issues related to data analysis and interpretation are discussed further in Section 6.

While EMAP's diagnostic capability is limited, we feel that the proposed approach will advance our ability to determine and quantify possible causes of regional and national declines in wetland condition. More detailed monitoring (e.g., during Tiers 3 and 4) and research efforts to determine cause-and-effect relationships can then be focused on those areas, stresses, and resource classes of greatest concern.

2.4 INTEGRATION

To meet the objectives of the EMAP-Wetlands program will require close cooperation with other federal and state agencies, interested groups, and many of the offices within EPA involved in wetland monitoring. Cooperative efforts that are ongoing or proposed involve issues related to program mandates, network design, indicators of wetland condition, and the logistics of field implementation. Details on the integration of EMAP-Wetlands with other relevant programs and interactions with other agencies and EPA offices are provided in Chapter 10. This subsection introduces only two of the most important integration activities, the relationship of EMAP-Wetlands (1) to the USFWS's NWI and (2) with other EMAP resource groups.

The most important coordination linkage, and one that is currently being actively pursued, is between EMAP-Wetlands and the NWI. As discussed in Section 1, the NWI is mandated by Congress to report on the status and trends in wetland **acreage** every 10 years. Given EMAP's goal to monitor and report on the status and trends in wetland **condition**, including acreage, cooperation between the two networks seems imperative, to take advantage of NWI's efforts and expertise in mapping and reporting on wetland acreage and trends. EPA and the USFWS have reached consensus on the following proposed delineation of roles:

- o The NWI will continue to be responsible for monitoring the status and trends in wetlands acreage and loss. Acreage statistics produced by EMAP in Tier 1 will be used by the USFWS, as appropriate, in their status and trends reports.

- o The EPA EMAP-Wetlands program will monitor and report on wetland ecological condition, using a composite of aerial landscape indices and field measurements.

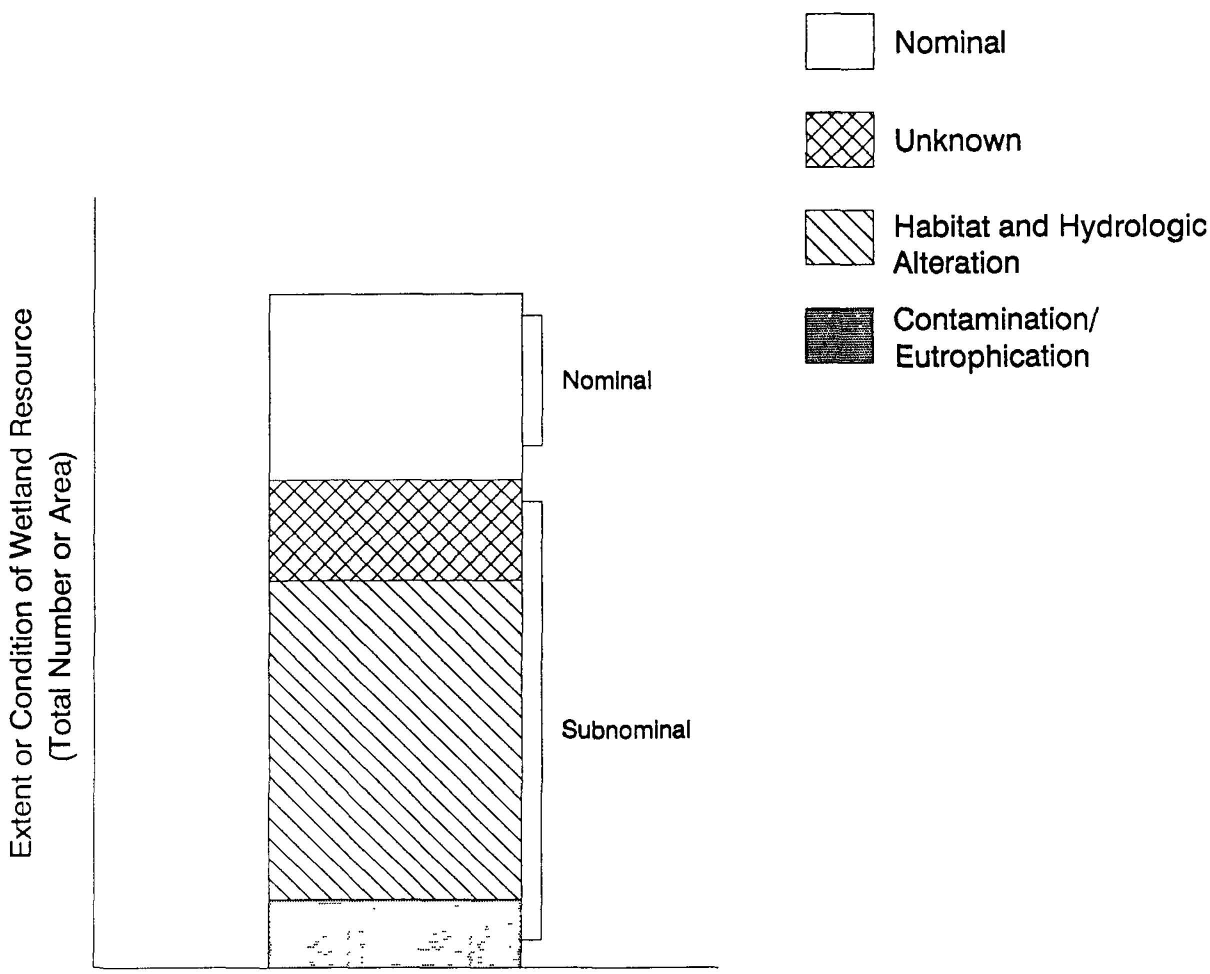

Figure 2-6. Hypothetical example: results from correlative approach to initial partitioning of subnominal systems among possible causes.

- Joint NWI-EMAP interpretative reports of both wetland extent and condition will be produced after the year 2005. Until that time, coordinated reports will be published by each agency to meet its own objectives.

As transitional areas between deepwater habitats and terrestrial systems, wetlands pose challenging resource boundary issues. EMAP-Wetlands must work closely, therefore, with the EMAP-Surface Waters, EMAP-Near Coastal, EMAP-Arid Lands, and EMAP-Forests resource groups to ensure that all major ecological resources classes are represented in EMAP and to avoid duplication. The proposed strategy for boundary coordination involves the following: (1) technically define the resource overlap, (2) outline the objectives of each group involved, (3) cooperatively develop a list of indicators to be monitored in these systems, (4) develop a strategy for cooperatively monitoring these systems, and ultimately, (5) report separately on these systems using the appropriate indicators of interest which address each resource group's specific objectives.

EMAP is not intended as a substitute for other monitoring and research programs, but instead is intended to provide a framework for integrating existing and new data, to better quantify and understand the status and trends of ecological resources in the United States. As a result, efforts to cooperate and coordinate with other offices, agencies, and organizations are a high priority within EMAP-Wetlands.

2.5 REPORTING

EMAP-Wetlands will produce four types of reports:

- annual statistical summary reports,
- interpretive reports
- specialized scientific reports, and
- scientific articles in peer-reviewed journals.

To be of maximum use, data must be transformed into useful information as quickly as possible. Therefore, annual statistical summaries will be published within nine months following collection of the last sampling for the year. Interpretive reports will be prepared for Congress, interested scientists, and decision makers every 5 years, after each sampling cycle. Joint interpretive reports with NWI will be produced after the year 2005. Special scientific reports and peer-reviewed papers will be produced periodically, to address particular topics of interest, for example, related to regional, stressor specific, or wetland-class specific issues. Detailed methods manuals for sampling wetlands will be developed and periodically updated. Further details on the types of reports to be produced are provided in Section 11.

2.6 IMPLEMENTATION PHASES

Several important design, indicator, and logistical issues need to be evaluated, field tested, and finalized before the EMAP-Wetlands program will be ready for full-scale implementation. This subsection describes the types of efforts which will be conducted to scientifically and operationally advance the EMAP-Wetlands group toward national monitoring of all wetland resources. Within a given region and wetland class, the proposed tasks will generally be completed in sequence.

2.6.1 Analysis of Data

The synthesis and evaluation of existing data provide a cost effective means to assess EMAP-Wetlands objectives. Examples of the types of issues that will be addressed include the following:

- Investigate the adequacy of the proposed EMAP network design and determine appropriate grid densities for each wetland class and region, by analyzing existing NWI digital data sets.
- Evaluate the proposed EMAP-Wetlands classification approach, particularly as it relates to the full Cowardin system used in the NWI, by analyzing existing NWI digital data sets.
- Quantify the spatial and temporal variability of proposed EMAP-Wetlands indicators for each wetland class within each region.
- Assess the responsiveness of each indicator to controlled or induced stress, or altered forcing functions (e.g., wetland hydrology).
- Provide retrospective or historical context for evaluating the status and trends in wetland acreage and condition.
- Perform simulations of expected indicator performance and proposed data analysis and interpretation techniques.

Data on wetland acreage and classes collected by the NWI will be used extensively to evaluate and refine the proposed EMAP-Wetlands sampling frame. Other types of data sets, of potential use for indicator development and evaluation, include (1) site-specific studies of wetland condition conducted for durations of greater than 5 years, (2) paleoecological studies of historical trends in wetland indicators, (3) regional data sets or surveys of wetland condition, and (4) experiments or monitoring programs investigating wetland responses to anthropogenic stressors. Further details on specific data sets proposed for analysis are provided in Sections 3.6 and 4.3.

2.6.2 Pilot Studies

Pilot studies are field projects conducted on one wetland type in one region with a limited set of indicators to meet one or more of the following objectives:

- Develop, evaluate, and refine sampling methods for indicators of wetland condition, for the specific wetland class and region of interest.
- Evaluate the ability of the proposed indicators to assess wetland condition at sites pre-selected using expert judgement to reflect both nominal and subnominal conditions.
- Quantify the temporal variability within the index sampling period to evaluate and refine proposed sampling protocols.
- Quantify indicator spatial variability, both within a given wetland and between sites.

Pilot studies will ultimately be conducted in all wetland types and all regions, prior to full-scale implementation (see Section 12).

2.6.3 Regional Demonstration Projects

Regional demonstration projects are field studies conducted in a survey mode using the EMAP-Wetlands frame and the proposed EMAP-Wetlands sampling protocols. Demonstration projects will be conducted for each wetland class and region; one-fourth of the Tier 2 sites for one region and wetland class will be sampled synoptically at a time. The objectives of these regional demonstrations include the following:

- Identify and resolve logistical problems associated with the program design.
- Gather the information necessary to evaluate alternative sampling designs and establish appropriate data quality objectives for the program.
- Evaluate the specificity, sensitivity, reliability, and repeatability of the responses of selected indicators over a broad range of environmental conditions.
- Generate data that can be used by the Office of Wetlands Protection and EPA Regions as tools to (1) establish wetland biocriteria, (2) establish designated use, and (3) identify sensitive wetland classes that need special regulatory consideration in order to be preserved with "no net loss".

2.6.4 National Implementation

The full-scale implementation of EMAP-Wetlands will ultimately involve the monitoring of wetland condition and extent in all of the proposed EMAP wetland classes in all regions of the country, utilizing the full suite of proposed response, exposure, habitat, and stressor indicators. The program will begin, however, with one regional demonstration project, monitoring one wetland class in one region, and then gradually scale up using the following proposed implementation priorities:

1. monitoring of the wetland class in additional regions, adding a new region each year until the wetland class is monitored nationally;
2. yearly additions of new wetland classes, starting in one region and then gradually expanding to other areas; and
3. expansion of the core list of indicators for national monitoring, as additional indicators are developed, tested, and approved.

The priority wetland classes and regions and associated timeline for implementation are presented in Figure 2-7; the rationale and specifics for each phase of EMAP-Wetlands testing and implementation are discussed in Section 12.

2.7 LIMITATIONS OF EMAP

To fully understand the proposed EMAP-Wetlands program, it is equally important to describe not only what the program will attempt to do, but also its limitations. EMAP is **not** intended to describe **all** components or attributes of an ecosystem or resource type. It is **not a process-oriented** research program and will **not** describe how systems **function**. It will, however, provide information on specific indicators measured during a specific index period, as a "snapshot" of the overall condition of a system.

EMAP-Wetlands has **not** been **optimized** to address any **specific stressors**, environmental problems, or policy questions, although such studies may be included within Tier 3. EMAP is **not** intended to be **compliance monitoring** and will not replace the need for these activities. In general, EMAP is intended to

CLASSES	REGIONS	1991	1992	1993	1994	1995
1. Salt Marsh	1. Southeast	PILOT →	DEMO →	IMPLEM →	→	→
	2. Mid Atlantic			DEMO →	IMPLEM →	→
	3. West Coast				DEMO →	IMPLEM
2. Flooded Emergents	1. Midwest (prairie potholes)		PILOT →	DEMO →	IMPLEM →	→
	2. Northeast				DEMO →	IMPLEM
3. Bottomland Hardwood	1. Southeast			PILOT →	DEMO →	IMPLEM
4. Saturated Emergents	1. Midwest (prairie potholes)				PILOT →	DEMO
5. Saturated Forested	1. Northeast					PILOT

Figure 2-7. Timeline and priority wetland classes and regions for EMAP-Wetlands field testing [pilot studies (PILOT) and regional demonstrations (DEMO)] and implementation (IMPLEM) through 1995.

provide a common sampling frame within which wetland condition can be assessed at a broad scale. The outputs from EMAP-Wetlands will be used to determine the relative magnitude and geographical location of various problems, to assist in establishing objective mitigation and research priorities. The monitoring program is not intended to be truly anticipatory, but rather to provide an ongoing monitoring framework within which new variables can be added or regional modifications can be made, so that the magnitude and extent of effects from newly identified problems can be determined more quickly.

3.0 MONITORING NETWORK DESIGN

This chapter provides further detail on the statistical design of the proposed EMAP-Wetlands monitoring network. The EMAP design objectives, strategy, and general approach are described in Section 3.1. Sections 3.2-3.6 then discuss specifics as they relate to monitoring wetlands. Section 3.2 provides background material on the NWI sampling frame. Section 3.3 describes the proposed EMAP-Wetlands classification system; Section 3.4, the Tier 1 sampling frame; and Section 3.5, proposed association rules for selection of the Tier 2 resource sampling units. At this time, many of the details on the EMAP-Wetlands monitoring network design have yet to be finalized. Thus, in Section 3.6, a brief outline is provided of planned future activities for design evaluation and refinement.

3.1 OVERVIEW OF EMAP DESIGN

The overall EMAP design strategy is to implement a permanent national sampling framework capable of the following:

- providing rigorous statistical answers regarding any explicit question about the status and condition of any regionally defined resource;
- providing baseline data leading to the rigorous detection and description of trends in the status and condition of regionally defined resources;
- identifying associations among attributes, both within and among resources;
- accommodating changes in resource definitions and classifications, and correction of errors; and
- quickly responding to new issues and questions.

Important requirements and features of the proposed design include the following:

- explicit definition of target populations and their sampling units;
- explicit definition of a frame for listing or otherwise representing all potential sampling units within each target population;
- use of probability samples selected from well defined sampling frames;
- flexibility to accommodate a variety of resource types and a variety of problems, some of which have not yet been specified;
- use of a hierarchial structure with the ability to sample at a coarser or finer level of resolution than the base grid density, giving flexibility at global, national, regional, or local scales;
- ability to focus on subpopulations or resource classes of potentially greater interest; and
- ability to quantify statistical uncertainty and sources of statistical variability for populations and subpopulations of interest.

The primary design strategy being considered to achieve these objectives is based on a systematic triangular grid of points randomly placed over the United States (see Figure 2-2). A fixed position, that represents a permanent location for the base grid, is established and the sampling points are generated by a random shift of the entire grid from this base location. This randomization establishes the systematic grid as a probability sample. Each point on the grid is separated by 27 km in each direction, resulting in approximately one point per 640 km^2 and about 12,600 points in the contiguous 48 states and about 2,400 points and 26 points in Alaska and Hawaii, respectively. Enhancement of the grid, to increase the sampling density for rare resources or areas of special interest, can be easily achieved by inserting additional grid points in a systematic pattern that is a factor of 3, 4, or 7 times that of the base grid density (Figure 3-1).

The grid-sampling process provides the capability of sampling any spatially distributed and well defined resource, including resources not currently specified. Randomization of the grid provides the protocol that generates a probability sample and ensures the desired rigor of population characterization. The triangular structure of the grid results in minimum distance between grid points and an additional degree of freedom from alignment with regular anthropogenic forms (e.g., state or county lines). If sample sizes are adequate, grid points can be post-stratified into meaningful strata [e.g., Winter's physiographic/climatic regions (Table 2-1) or EPA regions (Figure 2-3)] for reporting purposes. The hierarchial structure of the grid allows for resource descriptions at a coarser or higher resolution than the base grid. Ultimately, therefore, the EMAP grid could be modified as needed for sampling on multiple scales: global, national, regional, and local.

Following the placement of the grid, the area around each point will be characterized by ecological and land use criteria. Specifically, landscape descriptions will be completed for hexagons 40 km^2 in area centered on each grid point, representing one-sixteenth (6.25%) of the total area covered by the base grid (Figure 3-2). Using aerial photography, Landsat images, maps, and other existing information, the extent, numbers of units, and characteristics of the various ecological resource types within each 40 km^2 hexagon (40 hex) will be identified. These hexagon landscape descriptions constitute a probability area sample of the United States from which regional estimates of the structural properties for the resource can be generated. These structural properties include the numbers of resource units, their surface area, and other geometric and geophysical measures obtainable from remotely sensed sources, as well as land use and land cover data. The collection of resource units contained within these 40-hexes for any explicitly defined target population represents the Tier 1 sample.

For each ecological resource or resource class, a subsample of the resource units from the Tier 1 resource sample will be studied more intensively, using both additional remote sensing information as well as field sampling to assess ecological condition. This subsample (the Tier 2 resource sample) will be selected by probability methods and will be the basis for reporting on the regional status and trends in resource condition. The specific procedure for the Tier 2 sample selection will vary among resource groups (see Section 3.5). With the exception of certain questions requiring a joint effort, the selection of the Tier 2 samples will be conducted independently by each resource group. The number of sampling units used will depend on the precision and accuracy requirements for the resource. Some advantages of this double sample design are an increase in the precision of population estimates, an ability to identify resources via Tier 1 characterization not originally considered as part of the resource (e.g., lakes converted to wetlands and vice versa), and an ability to accommodate new issues as they emerge.

EMAP's objectives include both the description of current status and the detection of trends through time. These two monitoring objectives result in conflicting design objectives with regard to the optimal allocation of samples in space and time. Assessment of status is best done by making measurements on as many resource sampling units as possible, whereas trend detection is best done by repeatedly measuring the same units over time. The proposed design resolves this conflict by using a new set of resource sampling units for each year in four successive years, and then repeating the four-year cycle, using the same set of resource sampling units, in subsequent years (Figure 3-3). The sample sites are partitioned so that the same, systematic triangular grid (at one-fourth the density) is retained, to the degree possible, in each year

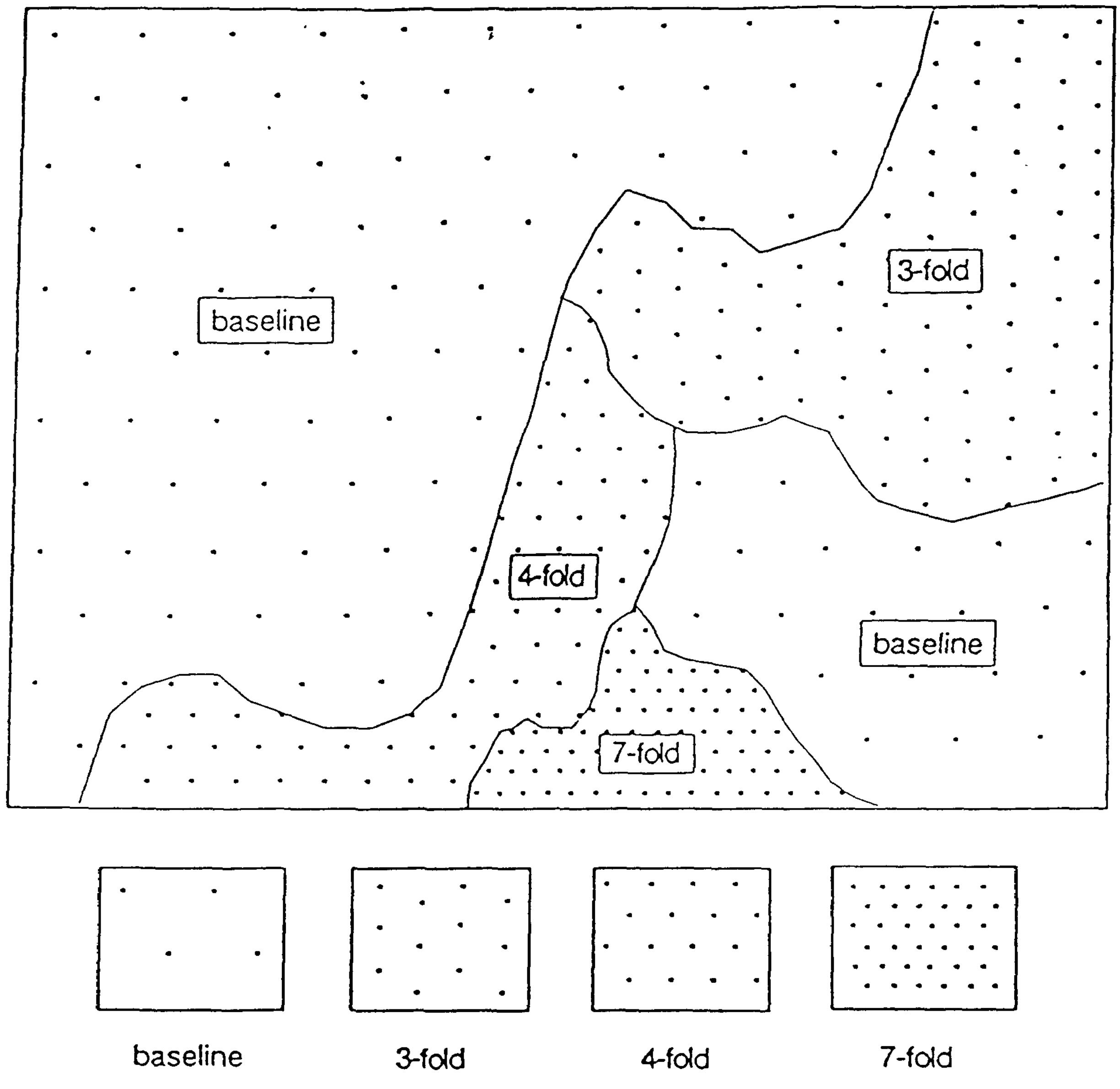

Figure 3-1. Enhancement factors for increasing the base grid sampling density.

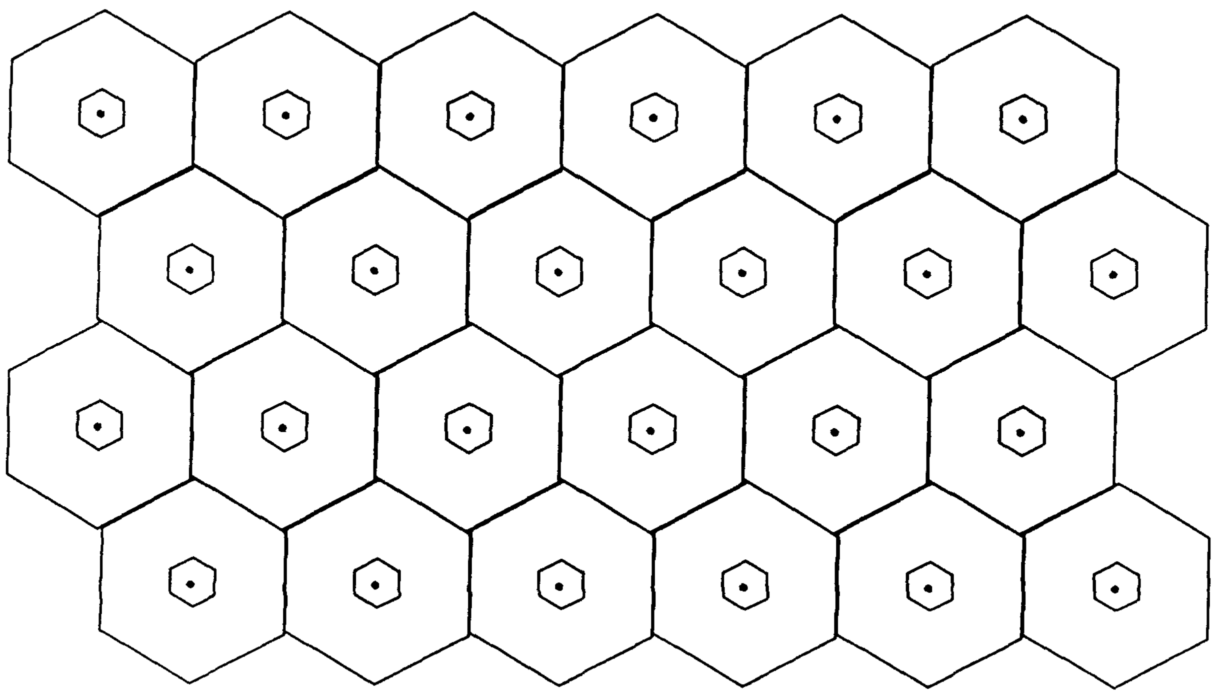

Figure 3-2. The landscape characterization hexagons are 1/16th of the total area and centered on the sampling points.

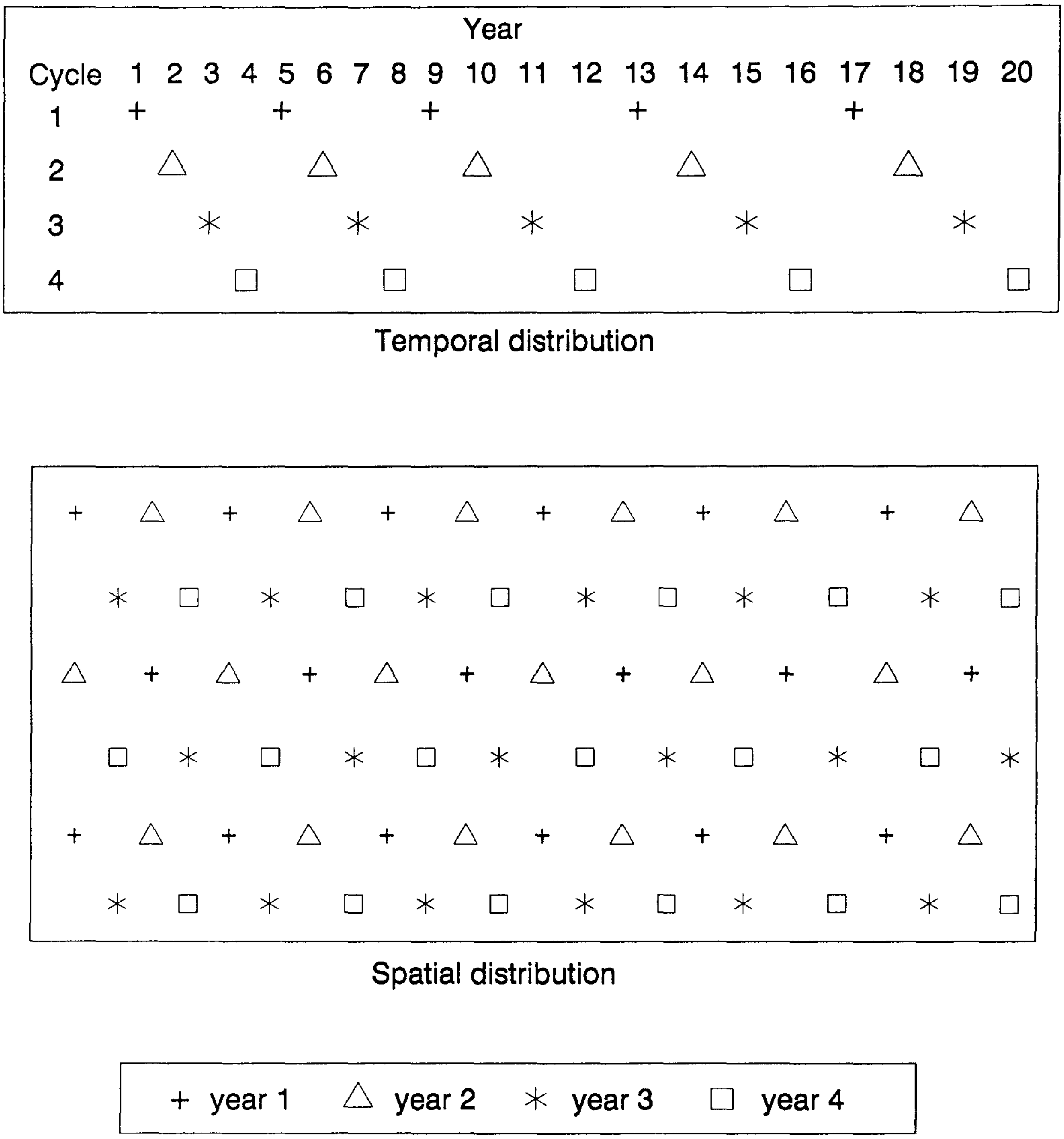

Figure 3-3. Spatially interpenetrating samples on a 4-year rotating cycle.

(see Figure 3-3). This interpenetrating design maintains nearly uniform spatial coverage for each annual subsample. Resource condition is estimated annually by using four-year running averages over the four interpenetrating subsets.

Initial simulation studies based on this design suggest that regional trends in response indicators on the order of 1% per year should be detectable within approximately 10-15 years. As additional data are collected and further design evaluation studies are completed, this basic proposed four-year sampling cycle may be modified, if necessary, to provide adequate sensitivity for detecting long-term trends in ecological condition (e.g., a subset of sites, selected as a probability subsample, may be studied annually).

The EMAP design will provide, therefore, statistically unbiased population estimates of status, trends, and associations among indicators with quantifiable confidence limits over regional and national scales for periods of years to decades. However, because individual sites are sampled only once every four years, EMAP will provide little information about conditions at any particular site.

Further details on the basic EMAP design and rationale for its selection can be found in the EMAP Design Report by Overton et al. (1990). Application of this design in the EMAP-Wetlands program is discussed in the following subsections.

3.2 RELATIONSHIP BETWEEN EMAP AND NWI

As discussed in Section 2.4, cooperative efforts are planned between EMAP-Wetlands and the NWI. This subsection provides a brief description of the NWI wetlands sampling design and opportunities for coordinating and integrating the EMAP-Wetlands design with the NWI.

In 1974, the USFWS directed its Office of Biological Services to design and conduct an inventory of the Nation's wetlands. The mandate was to develop and disseminate a technically sound, comprehensive data base concerning the characteristics and extent of wetland systems in the United States. Thus, the NWI Status and Trends Program was initiated.

Data for the NWI Status and Trends program are collected using a stratified random sample designed to detect changes in wetland acreage at the national level. The basic strata are formed by state boundaries and the 35 physical subdivisions described by Hammond (1970). Each individual stratum is defined as that portion of a physical subdivision bounded by state lines. Additional special interest strata are included to encompass wetlands in coastal regions and the Great Lakes. In total, 208 strata have been delineated in the conterminous United States (Frayer et al. 1983). Ongoing studies incorporate additional strata in Alaska.

Sample units are allocated to each strata in proportion to the expected amount of wetland and deepwater habitat acreage as estimated by earlier work (including Shaw and Fredine 1956). Sample units are selected randomly within each strata by first randomly selecting a 322 by 322 km (200 by 200 mile) grid section within the strata, and then randomly selecting a 3.2 km by 3.2 km (2 mile by 2 mile) sample unit within the 322 by 322 km grid. A total of 3635 sample units were used for the first national statistics report (Frayer et al. 1983)evaluating trends in wetland acreage from the 1950s to the 1970s. Each sample unit, therefore, is a 10 km^2 (four-square mile) area. Each unit is plotted on U.S. Geological Survey topographic maps. The extent and characteristics of wetlands within each unit are determined from aerial photographs (1:40,000 to 1:80,000). Observed changes in wetland and deepwater habitat from the 1950s to 1970s were also noted as being either natural or human induced, based on the photointerpretation. Wetland types were classified according to Cowardin et al. (1979) (Table 3-1), although Cowardin's hierarchical classification, including systems, subsystems, and classes, was aggregated into a smaller number of groups for reporting purposes.

Table 3-1. Cowardin Classification (Cowardin et al. 1979) of Wetlands and Deepwater Habitats.

System	Subsystem	Class
Marine	Subtidal	Rock Bottom
		Unconsolidated Bottom
		Aquatic Bed
		Reef
	Intertidal	Aquatic Bed
		Reef
		Rocky Shore
		Unconsolidated Shore
Estuarine	Subtidal	Rock Bottom
		Unconsolidated Bottom
		Aquatic Bed
		Reef
	Intertidal	Aquatic Bed
		Reef
		Streambed
		Rocky Shore
		Unconsolidated Shore
		Emergent Wetland
		Scrub-shrub Wetland
		Forested Wetland
Riverine	Tidal	Rock Bottom
		Unconsolidated Bottom
		Aquatic Bed
		Rocky Shore
		Unconsolidated Shore
		Emergent Wetland
	Lower Perennial	Rock Bottom
		Unconsolidated Bottom
		Aquatic Bed
		Rocky Shore
		Unconsolidated Shore
		Emergent Wetland
	Upper Perennial	Rock Bottom
		Unconsolidated Bottom
		Aquatic Bed
		Rocky Shore
		Unconsolidated Shore
	Intermittent	Streambed
Lacustrine	Limnetic	Rock Bottom
		Unconsolidated Bottom
		Aquatic Bed
	Littoral	Rock Bottom

Table 3-1. (cont.)

System	Subsystem	Class
Lacustrine (cont.)	Littoral	Unconsolidated Bottom
		Aquatic Bed
		Rocky Shore
		Unconsolidated Shore
		Emergent Wetland
Palustrine		Rock Bottom
		Unconsolidated Bottom
		Aquatic Bed
		Unconsolidated Shore
		Moss-Lichen Wetland
		Emergent Wetland
		Scrub-Shrub Wetland
		Forested Wetland

The NWI was designed to develop national statistics able to estimate the total acreage and changes in acreage for each wetland type within 10% of the true values with a 90% probability. Estimates produced by the survey include proportions of area and their standard errors, acreages and standard errors, and coefficients of variation. Although stratum-specific and state-specific results are compiled, estimates for many of these subpopulations are not considered reliable due to their small sample sizes (Frayer et al. 1983).

The Emergency Wetlands Resources Act requires that updates on wetland acreage and trends be reported at 10 year intervals, with reports due in 1990 (now under review), 2000, 2010, etc. In addition, recent budget increases for the NWI allow for more frequent reporting (every 5 years, or interim reports as needed) as well as an enhancement of the national grid for more precise region-specific estimates. Regional estimates of changes in wetland acreage are planned for the Atlantic and Gulf Coasts in 1992, the Great Lakes in 1993, and the Lower Mississippi River Alluvial Plain and Prairie Pothole regions in 1994.

Interactions between EMAP-Wetlands and the NWI will occur primarily at the Tier 1 resource definition phase. One of the major design objectives for EMAP-Wetlands is to maximize the compatibility between the two studies. It is proposed (see Sections 3.3 and 3.4) that the Tier 1 landscape characterization of EMAP's 40-hexes use **exactly the same techniques and criteria** as implemented in the NWI, preferably with the direct involvement of NWI personnel. All wetlands within EMAP's 40 km^2 hexagons will be classified according to the full Cowardin (1979) wetland classification (although aggregated groupings of the Cowardin classes will be used in selecting and reporting on the results for the Tier 2 resource sample; see Section 3.3). The EMAP habitat classifications will be compatible, therefore, with both the overall NWI mapping effort and the NWI Status and Trends program. Estimates of wetland acreage can be combined between the two national programs and reported either in terms of the NWI classes or the revised EMAP-Wetlands classification scheme.

The NWI and EMAP are based on two different sampling philosophies (one is a stratified random sample and the other is systematic), and not all statisticians agree on the optimal procedures for combining results from these two study designs. However, final point estimates for variables, such as acreage, can be combined using weighted averages, where the weights are inversely proportional to the sampling variances.

Consideration has also be given to conducting EMAP-Wetlands field sampling (at Tier 2) within the NWI Status and Trends sample plots. The NWI plots, however, are monitored remotely, and the exact location of these plots is not revealed to land owners or land managers. Field sampling would require access permission and identification of the sites to local and state resource management personnel. Previous studies suggest that these identified sites, once identified as be part of a national monitoring program, are often treated and managed somewhat differently. As a result, the monitored plots may no longer be representative of the target population of wetlands of interest, and the future integrity of the NWI Status and Trends design would be in question. For this primary reason, the NWI plots will not be used for monitoring wetland condition within EMAP-Wetlands. In addition, to maintain the integrity of the EMAP-Wetlands design, during each four-year cycle some EMAP-Wetlands sites will be dropped and new sites added, following strict guidelines, as described in Section 3.5. Additional reasons for deviating from the NWI design and sample units include the following:

- The NWI Status and Trends study was designed to detect changes in wetland acreage; thus, areas with greater wetland acreage were sampled more intensively. These same areas are not necessarily those most likely to experience changes in wetland quality; thus, the NWI design is not considered optimal for monitoring wetland condition.
- Many of the NWI Status and Trends plots are located in areas with a high density of fairly homogenous wetland types.
- Because of the NWI emphasis on areas with greater wetland acreage, reliance on the NWI plots would make it difficult to ensure an adequate sample size of rare wetland classes for EMAP-Wetlands.
- Tier 2 sites, if drawn from the NWI Status and Trends plots, would be selected with unequal probabilities and thus must be combined with unequal weights in all future analyses.
- Use of the NWI Status and Trends plots would decrease the compatibility between EMAP-Wetlands and the other EMAP resource groups.

Future activities and tasks planned as part of EMAP-Wetlands to ensure compatibility between EMAP and NWI include the following:

- Establish a steering committee with at least quarterly meetings to improve communication and interaction between NWI and EMAP, including other EMAP resource groups (Surface Waters, Near Coastal, Arid Lands, and Forests) as well as EMAP-Wetlands.
- Establish common dates for reporting on the status and trends in wetland acreage and condition; in addition, establish a date on or about the year 1995 for a major review of NWI and EMAP-Wetlands and to define future procedures for joint reporting after the year 2005.
- Through continued interaction with NWI, ensure that EMAP's Tier 1 characterization of wetlands within the 40-hexes is compatible with current NWI procedures, both with regard to the size of wetlands measured and wetland classification.
- Define the exact statistical procedures to be used for combining the EMAP-Wetlands and NWI data sets, and the associated precision goal for the combined statistics.

3.3 EMAP-WETLANDS CLASSIFICATION

At Tier 1, using 1:40,000-scale aerial imagery, the wetlands occurring within EMAP's 40 km^2 hexagons will be classified according to the aggregated Cowardin classification outlined in Table 3-2 (see Appendix B for additional detail). Subclasses of the Cowardin classification (Cowardin et al. 1979) have been aggregated to ensure that each EMAP-Wetlands class will be functionally distinct when sampled over a broad area for wetland condition. Additional constraints imposed by the EMAP design

- o limit the number of wetland classes to less than 20 classes per region to allow for adequate sample sizes per class, and
- o require distinct and logical boundaries between EMAP-Wetlands resource classes and those considered by EMAP-Surface Waters, Near Coastal, Forests, and Arid Lands.

The proposed EMAP-Wetlands classification system is based on vegetation cover type, water regimes, and the dominant water source (i.e., proximity to Riverine and Lacustrine systems), such that each class is characterized by a unique combination of natural forcing functions. Locator labels have been added to the EMAP-Wetlands classification system (see Table 3-2) to denote wetland units in the Palustrine system that share a common boundary with subclasses in the Riverine system ("R" locator) or Lacustrine system ("L" locator). Further details on the specific rules used to assign these locators are provided in Appendix B. Wetlands that are influenced by moving water (i.e., that are flooded by moving waters from streams or lakes) are distinguished, therefore, from wetlands in isolated basins (that receive water predominately from precipitation and runoff), acknowledging the important influence of water sources in determining wetland characteristics and processes. Given the need to distinguish wetland classes at Tier 1 based solely on aerial photography (1:40,000) and to automate the process of wetland classification using the data recorded by the NWI, this approach was considered the least arbitrary method for distinguishing among wetland hydrologic types. Wetlands close to, but with no common boundary with subclasses in the Riverine and Lacustrine systems, may also be influenced by flooded waters; however, the exact distance from the river, stream, or lake that delineates this realm of influence would vary depending on local topography and climate. Certainly, the proposed rules will result in some errors in correctly identifying all Palustrine wetlands on floodplains and all wetlands influenced by lake hydrology. Thus, during the first few years of the program, additional sources of information on wetland hydrology, including U.S. Geological Survey (USGS) topographic maps, aerial photography, and data from soil surveys, will be used to evaluate and refine these hydrologic labels and the EMAP-Wetlands classification.

As outlined in Table 3-2, the EMAP-Wetlands classification does not currently deal with Cowardin subclasses identified as having an artificial water regime (i.e., controlled by a dam or other water level control structure or method). Additional investigations will be need to determine how best to incorporate these systems within EMAP-Wetlands, as one or more distinct wetland classes.

The EMAP-Wetlands classes include all Cowardin classes within the Lacustrine, Palustrine, Riverine, and Estuarine systems with greater than 30% wetland vegetation cover. Cowardin deepwater classes are not considered as wetlands, and thus are excluded from the EMAP-Wetlands target population. It is assumed that the EMAP-Near Coastal and Surface Waters programs will monitor all other habitats mapped by NWI, including deepwater habitats, aquatic beds, and unconsolidated shores (mudflats). The specific Cowardin classes to be monitored by EMAP-Near Coastal and EMAP-Surface Waters are listed in Table 3-3.

The classes listed in Table 3-2 are referred to as target wetland classes, recognizing that the classification of wetlands at Tier 1 based on aerial photography will be imperfect. These classes provide the basis for selecting the Tier 2 sample; wetlands identified at Tier 1 will be pre-stratified as needed to ensure an

Table 3-2. Proposed EMAP-Wetlands Classes to be Included in Tiers 1 and 2 Sampling Frames for the Continental United States (developed by B. Wilen, USFWS, and R.E. Sullivan, Bionetics, Inc.).

System	EMAP Class[abc]	Cowardin Class[d]
Palustrine/ L - Locator[e]	Palustrine Vegetation L - Locator	Palustrine emergent forested or scrub-shrub wetland adjacent to a Lacustrine System (Limnetic or Littoral Subsystem)
Palustrine	Shallows	Palustrine Unconsolidated Bottom, Aquatic Bed, Unconsolidated Shore
	Emergent Temporary Flooded[g] Saturated[h] Seasonal-Permanent Flooded[i]	Palustrine Emergent Wetlands
Palustrine/ R - Locator[f]	Emergent R - Locator Temporary Flooded Saturated Seasonal-Permanent Flooded	Palustrine Emergent Wetlands adjacent to all Riverine Subsystems (except Intermittent)
Palustrine	Forest & Scrub-Shrub Temporary Flooded Saturated Seasonal-Permanent Flooded	Palustrine Forest and Scrub-Shrub Wetlands
Palustrine/ R - Locator	Forest & Scrub-Shrub R - Locator Temporary Flooded Saturated Seasonal-Permanent Flooded	Palustrine Forest and Scrub-Shrub Wetlands (including Dead Forested and Dead Scrub-Shrub wetlands) adjacent to all Riverine Subsystems (except Intermittent.)

Continued on the next page

Table 3-2. (cont.)

System	EMAP Class[abc]	Cowardin Class[d]
Estuarine	Emergent[j]	Emergent Wetlands
	Forested/Scrub Shrub	Forested Wetland and Scrub-Shrub Wetland

[a] The class of Moss-Lichen Wetland will only be included in Alaska.

[b] EMAP-Near Coastal will monitor Marine Subtidal Aquatic Beds and Estuarine Intertidal Unconsolidated Shore.

c Cowardin wetlands identified as having artificial water regimes have not yet been incorporated into the EMAP-Wetlands classification. A decision is pending on how best to incorporate these wetlands, as one or more distinct EMAP-Wetlands classes.

[d] Corresponding classes in the Classification of Wetlands and Deepwater Habitats of the United States (Cowardin et al. 1979).

[e] L - Locator identifies wetlands adjacent to lakes (see Appendix B for further details).

[f] R - Locator identifies wetlands adjacent to rivers and streams (see Appendix B for further details).

[g] Temporary flooded includes Intermittently Flooded, Temporary Flooded, and Temporary Tidal water regimes.

[h] Saturated includes Saturated and Seasonally Saturated water regimes.

[i] Seasonal-Permanent Flooded includes Seasonal Flooded, Semipermanently Flooded, Intermittently Exposed, Permanently Flooded, Seasonal Tidal, and Semipermanent Tidal water regimes.

[j] Includes only Emergent Wetlands in the water regimes Regularly Flooded and Irregularly Flooded. Subtidal and Irregularly Exposed (where land surfaces are exposed by tides less often than daily) are not included.

Table 3-3. EMAP-Near Coastal and EMAP-Surface Waters Cowardin Classification System Monitoring Responsibilities.

- o Classes in the Marine System
- o Classes in the Estuarine/Subtidal Subsystem
- o The classes Aquatic Bed, Reef, Streambed, Unconsolidated Shore, and Rocky Shore in the Estuarine/Intertidal Subsystem
- o The Emergent Wetlands in the Irregularly Exposed Water Regime of the Estuarine/Intertidal Subsystem (land surface exposed by tides less often than daily)
- o The classes Rock Bottom, Unconsolidated Bottom, Aquatic Bed, Unconsolidated Shore, Streambed, and Rocky Shore in the Riverine/Tidal Subsystem
- o The classes Rock Bottom, Unconsolidated Bottom, Aquatic Bed, Unconsolidated Shore, and Rocky Shore of the Riverine/Lower Perennial Subsystem
- o The classes Rock Bottom, Unconsolidated Bottom, Aquatic Bed, Unconsolidated Shore, and Rocky Shore of the Riverine/Upper Perennial Subsystem
- o The Riverine/Intermittent streambed class
- o Classes of the Lacustrine/Limnetic Subsystem (including Aquatic Bed)
- o The classes of Rock Bottom, Unconsolidated Bottom, Aquatic Bed, Unconsolidated Shore, and Rocky Shore of the Lacustrine/Littoral Subsystem

adequate sample size within each wetland class and region of interest to achieve the desired precision goals for regional population estimates (see Section 3.5). Procedures for dealing with misclassifications and changes in wetland classes over time are discussed in Section 3.5.4. During data analyses and in reporting the EMAP results on wetland condition, it may be desirable to further refine or to regroup these wetland classes, taking advantage of the additional data collected during Tier 2. These analyses may subsequently lead to an improved classification of wetlands, using aerial photography, at Tier 1. In addition, as part of the EMAP-Wetlands design evaluation efforts over the next several years, the proposed EMAP-Wetlands classification will be critically examined and tested, using existing data sets, from the NWI as well as data on wetland condition collected during field studies; other sources of information on wetland types (e.g., aerial photography, USGS topographic maps); and data collected during the EMAP-Wetlands pilot and regional demonstration studies.

3.4 TIER 1 SAMPLING FRAME

3.4.1 Discrete Resources

The conceptual universe of wetlands for EMAP-Wetlands is defined by "areas that are inundated or saturated by surface or ground water at a frequency or duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions" (33 CFR Section 328.3 and 40 CFR Section 230.3). The EMAP-Wetlands explicit Tier 1 target population consists of all wetlands

- o identified by the Cowardin classification system and that belong to one of the EMAP-Wetlands classes listed in Table 3-2; and

- o enclosed by a discrete polygon or identified as a one dimensional curve (linear wetland) during the mapping process as implemented by the USFWS's NWI.

Thus, vegetated wetlands, as defined for EMAP, do not represent all United States wetlands as delineated by the recent interagency wetland identification criteria (Federal Interagency Committee for Wetland Delineation 1989), primarily because of the limitations and errors associated with identifying and mapping wetlands using aerial photography rather than ground sampling. In particular, very small wetlands (generally < 0.5 ha) and those obscured by dense forest cover may not be visible on 1:40,000 aerial photographs used by NWI and, by definition, therefore are excluded from the EMAP-Wetlands target population. Wetlands, with insufficient vegetation cover (< 30%; see Section 3.3), would also not be included within EMAP-Wetlands. Periodic updating of the Tier 1 resource characterization (at approximately 10 year intervals) would, however, add any newly constructed, natural, or mitigated, vegetated wetlands visible on the updated aerial photographs to the target population.

The Tier 1 sample consists of all wetlands within the defined target population that occur within the 40 km^2 hexagons identified by the EMAP grid. Each Tier 1 discrete wetland polygon will be identified and later located by the coordinates associated with its centroid, or other well defined point, referred to as the polygon node. Linear wetlands will also be uniquely associated with a node, e.g., the end of the wetland which extends furthest to the north. A polygon or linear wetland whose node is located within a given 40-hex is defined as belonging to that hex and included, therefore, within the Tier 1 resource sample, even though part of the wetland may extend outside the hex. In the remainder of this document, discussions of sampling strategies for "polygons" also apply to linear wetlands.

Eventually, each discrete wetland unit in the Tier 1 sample will be identified and classified as part of the EMAP Landscape Characterization activities (see Norton et al. 1990; conducted cooperatively with the NWI as discussed in Section 3.2). In the near-term, however, because of the time required to complete new landscape descriptions for each of the EMAP 40-hexes, identification of the EMAP-Wetlands Tier 1 sample will rely on the available NWI paper maps and digitized data. As part of the NWI, maps of wetland occurrence are being developed for the entire United States, using the most up-to-date aerial photography available at the time of mapping. Disadvantages associated with relying on these existing maps include the following:

- o NWI maps have not been completed for all areas of the United States. For the seven major USFWS regions, completed maps are available for between 20 and 99% of the land area, depending on the region (Table 3-4).

- o Wetlands were mapped for different years in different regions, dating from the early 1970s to the late 1980s. Thus, the aggregate of available NWI maps cannot be used to quantify present-day wetland acreages, extent, and distribution.

Table 3-4. Percent of Area with NWI Mapping Completed, for Each Major USFWS Geographic Region.

Region		States Included	Percent Completed
1	Pacific NW	CA, HI, **ID**, **NV**, OR, WA, Guam, Samoa	75%
2	Southwest	AZ, NM, OK, TX	99%
3	N. Midwest	IL, IN, IO, MI, **MN**, MO, **OH**, **WI**	80%
4	Southeast	**AL**, **AR**, FL, GA, KT, **LA** **MS**, **NC**, PR, **SC**, TN, Virgin Islands	70%
5	Northeast	CN, DL, **ME**, MD, MA, NH, NJ, **NY**, PA, RI, VT, VA, WV	75%
6	S. Midwest	**CO**, **KS**, **MO**, NE, **ND**, **SD** **UT**, **WY**	45%
7	Alaska	**AK**	20%

Bold face indicates states that need to be mapped or updated (i.e., with maps >5 years old).

- New wetlands created since completion of the NWI maps would not be represented in the Tier 1 sample.

As part of the EMAP-Wetlands planning process, the numbers of 40-hexes in each of the interpenetrating samples not covered by NWI maps with recent imagery (e.g., less than five years old) will be determined. Costs will be estimated for (1) completing maps, using the NWI protocols, for 40-hexes that have not yet been characterized, (2) updating the maps developed from pre-1985 aerial imagery, and (3) expanding the NWI mapping protocols to adequately characterize all wetland classes of interest. Based on this information, decisions will be made regarding the specific techniques to be used to define the Tier 1 sample. The final EMAP-Wetlands design must account for changes that may occur in the Tier 1 sample and target population as (1) the maps and aerial photography used to identify the sample are updated and (2) the techniques available to remotely identify and classify wetlands are improved.

In special interest areas, for example, areas with rare but important wetlands, more intensive sampling may be required at the Tier 1 level than is provided by the base EMAP grid. Grid enhancement, as described in Section 3.1 (Figure 3-1), will be used to add additional 40-hexes, and their associated wetlands, as needed to the Tier 1 resource sample. The specific subregions requiring enhancement, and required sample sizes or enhancement factors, will be defined during later phases of EMAP implementation, most likely after the first four-year cycle of interpenetrating Tier 2 samples.

3.4.2 Extensive Resources

Some extensive wetland resources, because of their ecological uniqueness, importance, or size, may be reported separately, as individual estimates of specific wetland systems, and may be inappropriate for sampling as discrete wetland units during Tier 2 (see Section 3.5.2). The following wetlands are being considered as potential EMAP extensive resources (adapted from Mitsch and Gosselink 1986):

- Okefenokee,
- Great Salt Lake,
- Everglades,
- Great Dismal Swamp of North Carolina,
- Red Lake Peat Lands of Minnesota,
- Cedar swamps of Northern Michigan, and
- Atchafalaya floodway of Louisiana.

During Tier 1, the portion of these extensive systems intersected by the EMAP 40-hexes will be measured and characterized in the same manner as for all other wetland resources. These statistics can then be expanded to estimate the total area and attributes of the entire extensive wetland. The results may be reported separately or aggregated with other resource distribution and extent information for the region and appropriate wetland class(es).

3.5 TIER 2 RESOURCE SAMPLING UNITS

This section discusses the procedures for and associated issues related to the selection of the Tier 2 resource sampling units. Wetland association rules and the selection process are discussed for discrete wetlands in Section 3.5.1 and extensive wetland resources in Section 3.5.2. Issues related to implementing these procedures are then reviewed: denied site access (Section 3.5.3); misclassification and changes in wetland classes over time (Section 3.5.4); and site "rotation" to maintain the EMAP-Wetlands sample integrity (Section 3.5.5). Finally, the relationship between the Tier 2 EMAP-Wetlands sample and Tier 2 samples for EMAP-Surface Waters, Near Coastal, Forests, and Arid Lands is discussed in Section 3.5.6.

The number of Tier 2 wetland resource units sampled per wetland class per region will depend on (1) the precision goals for regional estimates of wetland condition within that target wetland class and region and (2), for some summary statistics (e.g., the population mean, median, or quartiles), the expected variability in the measured indicators of wetland condition. An operational guideline is that 50-100 wetland units should be sampled per wetland class and reporting region of interest (e.g., EPA regions; see Figure 2-3) over the first cycle of interpenetrating samples. In most instances, this sample size results in adequate population estimates of the distribution of indicator variables (i.e., cumulative probability distribution functions), so that changes in the tails of the distribution can be detected and traditional population parameters, such as the mean, median, variance, and population proportions (e.g., proportion of the class in nominal or subnominal condition), can be calculated. The results from the first four years of sample collection, as well as from the design evaluation studies described in Sections 2.6 and 3.6, will provide the information needed for more precise estimates of the optimal sample size per class and region.

3.5.1 Selection of Discrete Resource Units

The optimal procedures for selecting discrete wetland units for Tier 2 sampling are still being investigated (see Section 3.6). However, the basic approach is to (1) randomly select a subset of the 40-hexes in which wetlands of the class of interest occur and then (2) randomly select an individual wetland unit from each of the selected 40-hexes (Overton et al. 1990). Several alternatives exist to accomplish this task; for example, consider a given wetland class and region of interest:

1. Identify the complete array of 40-hexes in the region that contain one or more discrete wetland units of the wetland class of interest.

2. Develop a list of the discrete wetland units in the wetland class of interest that occur in each 40-hex.

3. Select a subset of these 40-hexes with the probability of selection proportional to the number of wetlands of that class in each 40-hex, while maintaining a spatially distributed sample within the region (discussed further below).

4. Randomly select one wetland unit per 40-hex.

This procedure selects hexes with a probability proportional to n, the number of wetland units identified within the 40-hex. Individual wetland units are then selected with a probability of 1/n; all wetland units within the hex have equal inclusion probabilities and thus equal weights. If desired, greater emphasis could be placed on wetlands in areas with more wetland acreage, by selecting the 40-hexes in Step 3 with a probability proportional to a, the total wetland area within each hex, rather than n. As before, one wetland unit would then be selected per hex, with all sites within a hex having equal inclusion probabilities. Use of the list, with either of the above site selection procedures, is preferred because it accurately portrays the universe of all identified and photointerpreted wetland polygons, yielding more data for management decisions.

For logistical reasons, related primarily to the expected time required to fully characterize and digitize all 40-hexes in a region, a second, alternative approach for site selection is currently being considered. Rather than select from a list of wetland units, the Tier 2 wetland unit could be defined simply by its position relative to the centroid (grid point) of the hexagon. Specifically, the wetland whose polygon node is closest to the center of the 40-hex would be selected for Tier 2 sampling. This "nearest neighbor" association rule is advantageous for common wetland resources because only a small number of wetland units would need to be digitized for site selection. On the other hand, calculation of the associated inclusion probability for the wetland unit is much more complex, requiring information on the Thiessen polygon associated with each node (see Overton et al. 1990). In the near-term, logistical constraints may result in the use of this second association rule. Research will be conducted during the design evaluation studies (Section 3.6) to evaluate the gain in efficiency resulting from the ease of selection of wetland units versus the loss in efficiency due to the difficulty of computing inclusion probabilities.

Both of the above proposed site selection procedures will have to be modified, somewhat, to account for the fact that some wetlands may no longer exist (especially for areas with maps that pre-date 1985) and access to many wetlands may be denied (see Section 3.5.3). One approach would be as follows:

- o Oversample (e.g., select three) wetland units within each 40-hex (either randomly from the list or by picking the three nearest neighbors).

- o Include in the Tier 2 sample all of the selected wetland units that still exist and can be accessed for field sampling.

These additional steps to temporally verify the occurrence and accessibility of each site will assure that adequate numbers of wetlands are sampled during Tier 2 for estimating the regional population parameters of interest. The Tier 2 target population, therefore, by necessity excludes sites that cannot be accessed for field sampling.

As noted in Section 3.4, problems may also arise for rare wetland classes. Inadequate numbers of Tier 2 units may be selected if these rare wetland classes occur in relatively few of the 40-hexes. Rather than increase the number of wetlands sampled within a given 40-hex, the preferred approach is to augment the 40-hexes by enhancing the basic EMAP grid (see Figure 3-1). The grid would be enhanced only in those areas with rare wetland resources, and the 40-hexes corresponding to the extra grid points would be photointerpreted only for the rare wetland resource classes of interest. Decisions regarding the need for and extent of grid enhancement will likely be made following the first four-year cycle of interpenetrating samples.

It is preferable that the Tier 2 monitoring sites be well distributed spatially throughout the region of interest. One procedure recommended in Overton et al. (1990) to ensure a spatially distributed Tier 2 sample is described here. The region of interest could be subdivided into areas or "subregions," with each area having approximately the same number of 40-hexes, where each 40-hex contains at least one member of the wetland class of interest. These areas can be identified subjectively or using some objective protocol. Each area should be spatially compact. The number of areas delineated within the region is determined by the desired Tier 2 sample size and the constraint that, if possible, two 40-hexes be chosen from each area.

For example, assume that the desired Tier 2 sample size for the wetland class Palustrine/Shallows in EPA Region 1 is 56; thus, 14 wetlands in the class and region will be visited each year. If there are 14 or fewer 40-hexes in the first interpenetrating sample that contain Palustrine/Shallows wetlands, then one Palustrine/Shallows wetland unit is selected from each. If more than 14 hexagons contain Palustrine/Shallows wetlands, then the appropriate 40-hexes are divided into seven spatially compact areas. For example, if there are 30 40-hexes with Palustrine/Shallows wetlands, the region would be divided into seven areas: five areas with four 40-hexes each and two with five 40-hexes per area. Two 40-hexes would then be selected from each of the seven areas with the selection probability proportional to the number of Palustrine/Shallows wetlands present in each area (within the 40-hexes). Finally, one Palustrine/Shallows wetland unit would be selected at random from each chosen 40-hex. The strategy to be used to ensure a spatially distributed Tier 2 sample is dependent on the final sampling plan recommended by the EMAP-Design and EMAP-Landscape Characterization groups.

Issues to be addressed and tasks to be completed during the design evaluation studies (Section 3.6) and early phases of EMAP-Wetlands implementation include the following:

- o Specific algorithms for Tier 2 site selection will be developed and peer reviewed.

- o The Tier 2 field sampling provides an opportunity for field verifying the Tier 1 wetland classification and characterization. For compatibility with the NWI, EMAP-Wetlands will consider adopting the same standard operating procedures and field data sheets as used for NWI's field verification.

- o In some wetlands, it may be difficult to relocate every four years the same sampling point for data collection, because boundaries and landmarks may not be obvious in the field. Imprecise location of sampling sites may contribute to indicator variability and thus detract from the precision of statistical comparisons. Information collected in pilot studies or from existing data sets may be used to assess the relative importance of small variations in sampling location. In addition, the importance of and guidelines for locating the same point or transect in subsequent sampling years will be included in the EMAP-Wetlands Field Training and Operations Manual.

3.5.2 Selection of Tier 2 Sampling Units for Extensive Resources

As noted in Section 3.4, separate reporting on extensive wetland resources may be advantageous in cases of large homogeneous wetlands or areas that are ecologically distinctive. Overton et al. (1990) suggest that resource units 2,000 hectares or larger (i.e., covering an area at least one half the size of the landscape characterization hexagon) be considered for sampling as extensive, rather than discrete resource units.

Extensive wetlands would be sampled using the EMAP grid to locate points within the resource. At each point on the grid intersecting the extensive wetland, indicator measurements would be collected (either at the specific grid point or using transects, quadrants or other appropriate sampling methods as proposed in Section 4 for each indicator). In general, to obtain adequate estimates of population parameters, such as cumulative distribution functions or the population mean and variance, 50-100 sampling sites (points on the grid) would be required. Thus, grid enhancement (Section 3.1) may be necessary.

Heterogeneous extensive wetlands pose particular problems. Several wetland classes may occur within a given heterogeneous system. Thus, 200 or more sampling sites may be needed to adequately characterize the entire wetland (50-100 sites per wetland class). Because of the large amount of effort required, it is unlikely that EMAP-Wetlands will attempt to report on the status of individual heterogeneous extensive wetlands. Instead, these resources will be sampled in the same manner as for discrete wetlands, and reported on as a component of the regional resource estimates for each EMAP-Wetland class.

While it may be feasible to develop separate population estimates for relatively homogeneous extensive wetlands, the degree of effort to be applied to this task in EMAP-Wetlands has not yet been decided.

3.5.3 Denied Access to Tier 2 Sites

One of the most serious problems facing the EMAP-Wetlands program at Tier 2 is the strong possibility that land owners or management agencies may deny access to some selected wetland units. All available means will be used to gain access and to ensure that each wetland remains representative of the wetland target population (see Section 3.5.5) for at least two cycles of the program.

There is no scientifically accepted procedure for replacing wetland units that cannot be sampled, which will result in unbiased population estimates. Because of the potential for denied access to some sites, the number of wetland units selected for Tier 2 will exceed the required number for population estimation (see Section 3.5.1). All sites that can be accessed will then be field sampled. Regional estimates of wetland condition in Tier 2 will apply, therefore, specifically to the redefined target population of all **accessible** wetland resources. The inclusion probabilities for inaccessible sites and information from Tier 1 provide the basis for estimating the numbers, area, and general structural properties of inaccessible wetland resources.

Informed local government agency personnel, e.g., county agents with the Soil Conservation Service (SCS), will be actively involved in all contacts with land owners and managers. EMAP-Wetlands field teams will receive training on how to communicate effectively with individual land owners/managers and the general public during field operations.

3.5.4 Wetland Misclassification

Errors in the Tier 1 classification of wetlands, based on aerial photography, are likely to be detected during the Tier 2 field sampling. Three types of misclassification are possible: (1) the wetland unit may belong in a different target EMAP-Wetlands class than expected from the Tier 1 photointerpretation; (2) sites identified as wetlands during Tier 1 may be found to be non-wetlands (i.e., resources not included in the EMAP-Wetlands target population, such as deepwater habitats and parking lots) when visited in the field; or (3) true wetlands may be overlooked (misclassified as non-wetlands) during Tier 1 and thus not included in the EMAP-Wetlands sampling frame. Errors of the first type have little effect on the integrity of the EMAP-Wetlands design; shifts among wetland classes can be accounted for during data analysis. Errors of the second or third type, however, are of greater concern. If the wetland/non-wetland error rate is significant during Tier 1, then the EMAP-Wetlands target population will be poorly defined; or alternatively, the target population must be operationally defined.

Data collected as part of the NWI Status and Trends program provide a basis for estimating the error rates associated with classifying wetlands from aerial photography. Misclassification rates **among** Cowardin subclasses (i.e., wetland units classified in the NWI found to be misclassified in the wrong Cowardin subclass during NWI field verification studies) are generally less than 15%. Much of this error was associated with distinguishing among water regimes. Thus, error rates for the aggregated subclasses and aggregated water regimes to be used for EMAP-Wetlands are likely to be significantly less, and wetland/non-wetland error rates should be substantially lower than for misclassifications among individual EMAP-Wetland classes. As a result, extensive problems with target population definition in Tier 1 are not expected. Additional analyses of the NWI data base to address these issues are planned as part of the design evaluation studies noted in Section 3.6.

All wetland units selected for Tier 2 will be sampled in the field. Data collection activities will be curtailed only in those cases where the selected site is found to be a non-wetland. Misclassified wetlands will be sampled using field protocols appropriate for their actual target wetland class (e.g., wetlands selected as a Palustrine/Emergent wetland but found in the field to be a Palustrine/Shallows wetland will be sampled in the same manner as for all other Palustrine/Shallows wetlands). Likewise, data for misclassified sites must be analyzed as a member of the correct target wetland class. Units "transferred" across wetland classes for data analysis will carry unequal weights, complicating computations but causing no bias in the resulting target population estimates for each class.

Wetland units identified as misclassified during Tier 2 will be used to estimate the overall Tier 1 misclassification rate, for adjustment of the Tier 1 target population estimates. If the Tier 1 error rates are significant, revision of the Tier 1 protocols and perhaps the EMAP-Wetlands classification system may be appropriate (e.g., by pooling commonly misclassified wetland classes). Rare wetland classes must be maintained, however, even if subject to large misclassification rates.

Wetland boundaries delineated during the Tier 1 photointerpretation may also not match those observed during the Tier 2 field sampling. In most cases, however, the Tier 1 "permanent" resource boundaries will **not** be altered during field sampling, because the timing of the visit may not be representative of the long-term extent of the wetland. The field crew will, however, document the new boundaries. Only in extenuating circumstances (to be defined in the Field Training and Operations Manual) will the field crew be allowed to permanently change the resource boundary, with associated changes in site(s) for indicator measurements.

Misclassified sites and apparent problems with resource boundaries will result from both errors in photointerpretation as well as actual changes in the landscape over time. Wetland units will shift from one class to another; new wetlands may be created, through human actions or natural succession, and others lost. To detect these trends will require periodic updates of the Tier 1 landscape characterization, preferably on the same four-year interpenetrating cycle as for Tier 2 sampling (see Section 3.1; Figure 3-3). Logistical and funding constraints may necessitate a somewhat longer Tier 1 cycle, however (see Norton et al. 1990). Information gained in Tier 2 sampling and improved technology may also enhance the ability to better interpret future photographs. New perspectives and technology may suggest reclassifications which are more meaningful. As a result, restratification of the Tier 2 samples may be appropriate at each cycle for improved statistical precision. The optimal approach for managing changes over time in the target resource classes is a general problem within EMAP and must also be addressed by the EMAP-Design group and the other EMAP resource groups.

3.5.5 Rotation of Sampling Sites

Over a four year period, each wetland unit in the Tier 2 sample will be studied. The cycle will be repeated every four years, revisiting **most** of the Tier 2 sites. Current plans call for rotating some sites out and adding new sites in each cycle, so that no bias is introduced by EMAP-Wetlands sites being treated in a different manner than for non-monitored sites. Some level of site rotation is needed to ensure that the sites sampled in Tier 2 continue to represent the EMAP-Wetlands target population of interest.

It is proposed that a percentage of the sample units would be rotated out of the study on a regular basis, so that a given wetland unit would be "in the sample" for 16 years (4 cycles of 4 years) before replacement. In addition, based on the results from previous monitoring cycles, sample sizes per class can be adjusted as needed to accommodate requests for increased precision in variable estimates, or decreased precision if sample sizes are found to be unnecessarily large.

3.5.6 Relationships with Other Resource Groups

Concerns regarding wetland/non-wetland misclassification rates (Section 3.5.4) would be reduced if all EMAP resource groups applied comparable Tier 2 sampling frames, allowing detection and estimation of resources misclassified across resource boundaries during Tier 1 (e.g., wetlands misclassified as lakes). However, for logistical reasons, different frames have been proposed by different resource groups. For example, EMAP-Surface Waters has proposed using Digital Line Graphs from 1:100,000-scale maps provided by the USGS. In general, lakes to be sampled in Tier 2 include units which are classified by the USGS as reservoirs, lakes, or ponds on these digitized maps. EMAP-Near Coastal plans to sample list frames for estuarine systems that can be individually identified and to sample extensive estuaries using the EMAP grid.

Advantages of using the same sampling frame for Tier 2 sampling for all or most ecological resources include

- o common documentation of partitioned units into mutually exclusive and exhaustive units,
- o assurance that proposed monitored classes are not excluded because of exclusive data base and map scales, and
- o documentation of resource classes to be **temporally** deleted from the EMAP program.

In some cases, wetland units may be classified and monitored by more than one EMAP resource groups, e.g., forested wetlands and agricultural wetlands. Such units should be in the Tier 2 sampling frame for each appropriate resource group and are subject to Tier 2 sampling by one or more groups. Overlap of responsibility for reporting on the condition of these resource units is expected (see Section 2.4).

Issues related to program integration and joint efforts at sampling common resources require further discussion and consideration. Within EMAP, these responsibilities fall with each of the resource group technical directors as well as with the EMAP Integration and Assessment task group. In particular, decisions will be made regarding when and if EMAP-Wetlands, Surface Waters, Near Coastal, Forests, and Arid Lands will use the same sampling frame for selection of Tier 2 units (e.g., sampling riparian wetlands using the EMAP-Surfaces Waters sampling frame for streams). In addition, comparisons among proposed sampling frames will be completed to ensure that all habitat types of interest (wetlands, ponds, riparian habitat, marine aquatic beds, etc.) are incorporated within the appropriate component of the EMAP monitoring network.

3.6 FUTURE DESIGN RESEARCH NEEDS

The priority design research needs and tasks planned for finalizing the EMAP-Wetlands monitoring network design fall into five general categories: (1) theoretical statistical design issues, (2) coordination with NWI and other EMAP resource groups, (3) analysis of existing digitized data sets, (4) field pilot studies, and (5) regional demonstration projects.

3.6.1 Theoretical Statistical Design

The remaining EMAP design issues will be addressed in a collaborative effort between the EMAP Design task group and EMAP-Wetlands statisticians. Resolution of the following tasks will assure a successful data gathering and interpretation effort. Tasks related to Tier I include the following:

- Evaluate the adequacy of the proposed EMAP grid density and options for grid enhancement within regions sampled for rare resources.
- Develop statistical procedures for population estimates that account for changes over time in discrete resource boundaries; changes in wetland characteristics over time that result in shifts among wetland classes (as well as between resource groups); and the addition of new resources (wetlands) identified in subsequent cycles of Tier 1.
- Establish statistical procedures for combining acreage estimates from the NWI and Tier 1 of EMAP-Wetlands and EMAP-Surface Waters.
- Develop statistical algorithms for correcting Tier 1 parameter estimates to account for misclassification rates.
- Specify statistical procedures for combining parameter estimates from samples of both discrete wetland units and extensive wetland resources.

Tasks related to Tier 2 include the following:

- Develop statistical techniques which yield approximately equal inclusion probabilities for Tier 2 wetland classes when units are dropped and others subsequently added to classes in future EMAP sampling cycles.
- Develop standard operating procedures for incorporating changes in resource boundaries detected during Tier 2 visits.

EMAP and EMAP-Wetlands statisticians will prioritize and address these tasks over the next several years as part of the continuing EMAP-Wetlands planning and evaluation activities prior to full-scale implementation.

3.6.2 Coordination with NWI and Other EMAP Resource Groups

To ensure the successful integration of NWI and EMAP-Wetlands, several design issues remain to be resolved. These include the following:

- o Establish statistical precision goals for the combined acreage estimates from the NWI and EMAP.
- o Develop standard operating procedures, consistent with those applied in the NWI, for field verifying the 40-hex landscape characterizations. This sample for quality control should be completed **before** the Tier 2 sample sites are selected.
- o Develop standard operating procedures for reporting, verifying, and incorporating changes (and related systematic errors) in classification and wetland boundaries into the EMAP and subsequently NWI data bases.
- o Investigate the possibility of incorporating a digitizing package, Tier 1 data storage, sample site selection, Tier 2 data storage (in the field), and data retrieval into one overall computerized procedure.
- o Establish a date (around 1995) for a major review of the two programs (NWI and EMAP) to settle the remaining issues and procedures for joint reporting on the extent and condition of wetlands. Establish common reporting dates for coordinated NWI-EMAP reporting of status and trends.

Coordinated NWI-EMAP meetings will be conducted to address these issues.

Meetings will also be held with other EMAP resource groups to investigate the use of the same or at least compatible sampling frames for Tier 2 site selection. Specific plans will be developed for data integration and exchange among resource groups. General issues relating to EMAP integration and design compatibility will be addressed by the EMAP Steering Committee during the upcoming year.

3.6.3 Wetlands Design Evaluation Study

Computer simulation exercises will be conducted using existing NWI digitized data to complete the following tasks:

- o Estimate expected maximum Tier 2 sample sizes (per wetland class and region), using various grid densities (first in Illinois, then in Washington and the Prairie Pothole region).
- o Compare the costs and expected efficiency of the proposed alternative Tier 2 site selection rules; also, evaluate the utility of the proposed procedures for maintaining a spatially distributed Tier 2 sample.
- o Evaluate the EMAP-Wetlands proposed wetland classification system using several state digital wetland data bases to determine the frequency of occurrence of units in each class.

Many of the above tasks will be completed as part of the proposed 1991 design evaluation study. A joint report will be prepared by EMAP-Wetlands, NWI, and EMAP-Landscape Characterization personnel, assessing the proposed EMAP grid density, classification, and Tier 2 site selection rules.

In addition, a trends simulation study will be conducted to quantify the statistical power of the EMAP design for detecting regional and national trends in wetland acreage and condition using the proposed EMAP-

Wetlands indicators. A regional data set will be simulated that incorporates spatial and temporal variation, population variation, analytical uncertainty, and the expected indicator distributions.

3.6.4 Field Pilot Study

During the proposed field pilot study (Section 2.6), additional data will be collected for design evaluation, and specific logistical issues which impact the Tier 2 design and data analysis will be addressed:

- Evaluate the utility and variation inherent in the proposed EMAP-Wetlands index period.
- Quantify indicator variability and its influence on the EMAP-Wetlands detection of long-term trends in wetland condition.
- Define criteria and procedures for selecting reference sites, and for applying reference site data to determine nominal and subnominal conditions.
- Develop standard operating procedures, for site visits and measurement of indicator variables which
    - locate and permanently identify a fixed point or transect for future visits,
    - inform field crews of procedures to follow when they find that their field site is misclassified,
    - include the NWI procedures for field verifying Tier 1 landscape characterizations, and
    - provide guidance and training to help Tier 2 field crews communicate effectively with the public and individual land owners/managers.

3.6.5 Regional Demonstration Project

The regional demonstration projects provide the first opportunity to assess many of the EMAP-Wetlands major design and logistical issues. Prior to conducting the first regional demonstration, planned for the autumn of 1992 (see Section 12), the following tasks must be completed:

- Initiate a long term cooperative agreement with the Department of Agriculture SCS for assistance in gaining access to Tier 2 sites.
- Reevaluate the standard operating procedures developed for the field pilot study.
- Determine the boundaries of linear wetlands to be included in the EMAP-Wetlands program.
- Select Tier 2 sites from existing NWI digitized maps.

Data from the regional demonstration study will be used to

- estimate the percentage of sites where access was denied;
- estimate and document the percentage of sites which were misclassified;
- estimate and document the percentage of sites which experienced boundary definition problems;
- better estimate the costs of fully characterizing each of the EMAP 40-hexes; and

- refine the trend simulation studies (described in Section 3.6.3), to better evaluate the power of the EMAP-Wetlands design for detecting trends.

These results will then be used to modify as needed and improve the EMAP monitoring network design prior to national implementation.

4.0 INDICATORS OF WETLAND CONDITION

This chapter provides additional information on the proposed EMAP-Wetlands indicators of wetland condition and our approach to indicator development and testing. An overview of the indicator development process is presented in Section 4.1. Section 4.2 then outlines the rationale, proposed approach, and remaining research needs for each of the EMAP-Wetlands indicators. Finally, in Section 4.3, priority research tasks are proposed to further advance the process of indicator selection and evaluation towards national implementation of the EMAP-Wetlands monitoring program.

4.1 FRAMEWORK FOR INDICATOR DEVELOPMENT

The use of indicators to assess wetland condition or "health" is central to the EMAP concept. It assumes that meaningful information can be obtained for regional assessments of important wetland attributes based on a fairly constrained and limited set of indicator measurements, collected once every four years during a prescribed index period. Identification of the best set of indicators to achieve this objective is critical, therefore, to the success of EMAP-Wetlands. While there are many indicators of potential value for characterizing wetland condition (see Adamus and Brandt 1990), only a select subset of these indicators can be monitored given the available funding resources and desired regional scope of the EMAP-Wetlands program.

The development and selection of indicators for EMAP-Wetlands is viewed as a continual process, now in its fairly early stages. A basic framework for indicator identification and evaluation has been defined (Figure 4-1) and an initial set of potential indicators of wetland condition has been proposed (see Figure 2-5). Both the process and the indicator list will be expanded, refined, and improved as part of the research and development activities proposed for EMAP-Wetlands over the next several years (Section 4.3).

The framework for indicator development (Figure 4-1) is intended to serve three primary functions: (1) **encourage consistency** across EMAP resource groups, (2) **ensure completeness** in the overall set of indicators monitored so that significant ecological changes on regional scales do not escape detection, and (3) **provide flexibility** over time to accommodate new knowledge and ideas (Knapp et al. 1990). The six phases of the indicator development process define the sequence of activities required to identify candidate indicators and advance them to the stage where they can be implemented regionally and nationally within the EMAP-Wetlands monitoring network:

Phase 1: Identification of issues (environmental values and apparent stressors) and assessment endpoints

Phase 2: Identification of a set of **candidate indicators** which are linked to the identified endpoints and responsive to expected stressors

Phase 3: Screening of the candidate indicators based on a set of indicator evaluation criteria and the wetland conceptual model, selecting as **research indicators** those that appear to fulfill key requirements

Phase 4: Quantitative testing and evaluation of the expected performance of research indicators in field pilot studies or through analysis of existing data sets, to identify the subset of **developmental indicators** suitable for regional demonstration projects

EMAP INDICATOR EVOLUTION

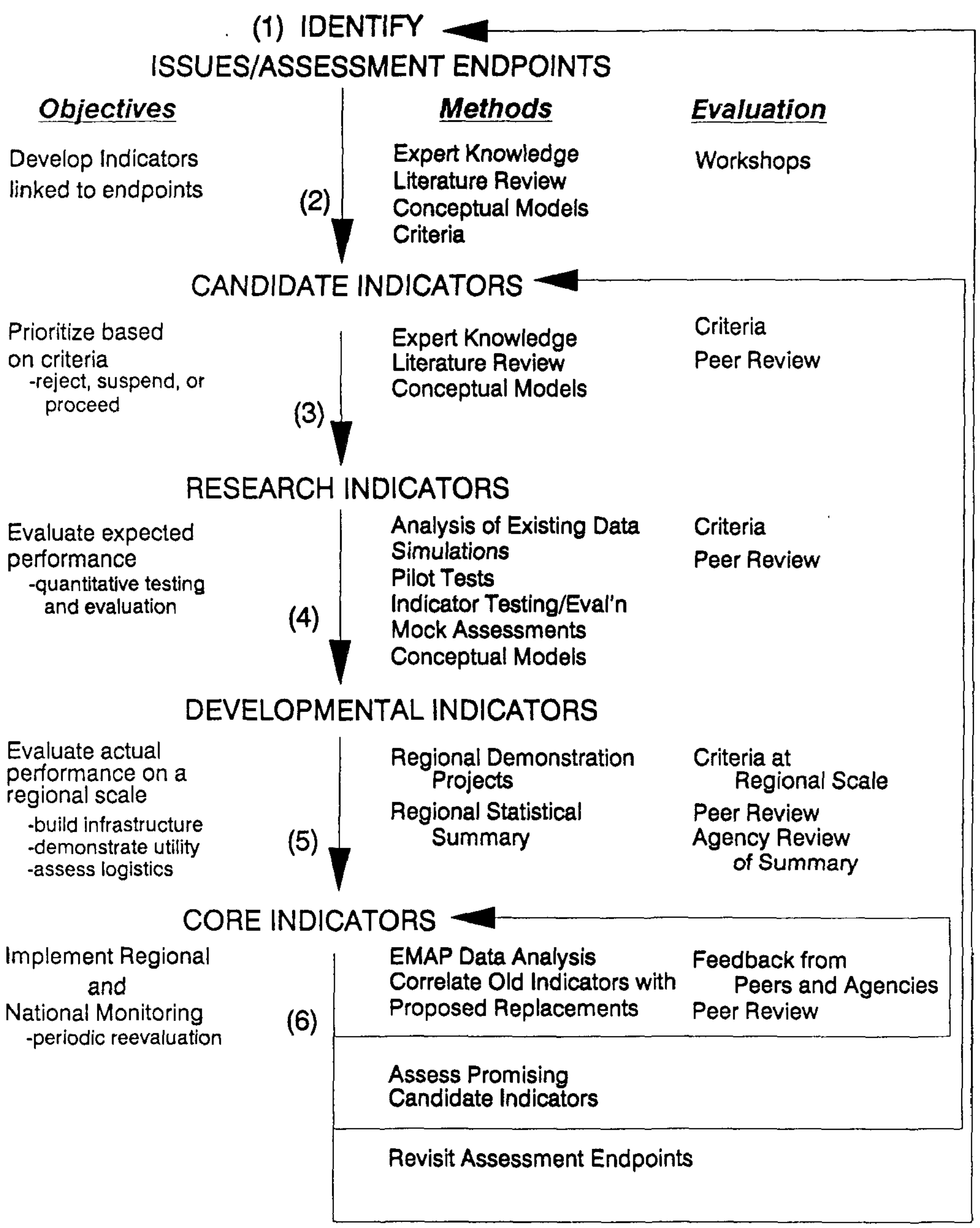

Figure 4-1. Framework for indicator development.

Phase 5: Regional scale demonstration of developmental indicators, using the sampling frame, methods, and data analyses intended for the full core EMAP-Wetlands network, to identify a subset of **core indicators** suitable for full-scale implementation

Phase 6: Periodic reevaluation and refinement of the core indicators as needed within the national EMAP-Wetlands monitoring network.

It is critical to the success of EMAP that the characteristics of the environment monitored are appropriate to the program's assessment goals, defined in Section 1. The first phase of the indicator development process, therefore, is intended to establish a foundation for indicator interpretation, by identifying the environmental values, assessment endpoints, and major stressors of concern for the resource. In Section 1.3, three primary values associated with wetlands were identified:

1. ecological support,

2. hydrologic functions, and

3. water quality functions.

The ability of a wetland to sustain these three functions or values we believe is reflected in three primary wetland attributes (defined in Section 2.2):

1. productivity,

2. biodiversity, and

3. sustainability.

These three attributes have been selected, therefore, as assessment endpoints for the EMAP-Wetlands program.

To serve as monitors of human-induced impacts on the environment, the collective set of indicators selected must not only be indicative of wetland condition but also responsive to the primary environmental stressors of concern. As noted in Section 1.3, major stressors of wetland systems include

- hydrologic source alteration,
- direct physical alteration,
- toxic contaminant influx, and
- nutrient loadings.

Other factors, such as global climate change and invasion of exotic or nuisance species, are also of concern.

These listings of values, assessment endpoints, and stressors establish the boundaries for defining wetland health. Conceptual models are then used to help delineate important linkages between the endpoints and stressors, to be monitored using response, exposure, habitat, and stressor indicators (defined in Section 2.2). The development of a conceptual model is considered an essential part of the indicator development process. The model serves two primary purposes:

1. **to explicitly define the framework for indicator interpretation**, e.g., how the response indicators relate to assessment endpoints; and

2. **to identify any gaps within the proposed indicator group**, i.e., missing links or components for which additional or new indicators are needed.

Conceptual models can be constructed at many scales, from basic models which demonstrate only the major components of the system (e.g., Figure 4-2) to complex models identifying all known existing linkages. In each instance, the objective is to delineate important wetland characteristics and the major stressors and factors that affect them.

The EMAP-Wetlands program is in the process of developing an explicit conceptual model that will identify and link the proposed wetlands assessment endpoints, indicators, and major stressors. Our approach for assessing wetland condition can be illustrated with a single stressor, single endpoint conceptual model (Figure 4-3). Changes in land use patterns may reduce wetland acreage in an agricultural landscape (**Stressor Indicators**) and consequently alter the hydrology and increase contaminant loadings in the remaining wetlands. Changes in hydrology and reduction in the quality of water entering the wetlands (**Exposure Indicators**) may result in habitat modification and chemical contamination (**Impacts**). Biotic responses to these impacts may include shifts in plant and animal species composition and diversity (**Response Indicators**). Adverse changes in the productivity, biodiversity and sustainability (**Assessment Endpoints**) can be detected from an evaluation of these indicators or combined indices of indicator changes (see Section 6). Based on this information, some proportion of the wetlands in the region may be classified as subnominal and, thus, may not be performing functions as expected by society. In a similar manner, quantitative process-oriented models (e.g., Mitsch et al. 1988, Costanza et al. 1989) may also be used as an aid to select and interpret indicators for EMAP-Wetlands.

Building upon the foundation provided by the conceptual model (and/or quantitative simulation models), phase 2 of the indicator development process involves the identification of candidate indicators, i.e., a full listing of all potentially useful indicators of both wetland condition and factors that affect wetland condition. Generation of this list is considered an ongoing and continual process, incorporating new ideas and proposed indicators as they become available.

The next three phases of the process are oriented towards critical evaluation and iterative filtering of the set of candidate indicators down to a defensible, practical set of core indicators. The process of testing and prioritizing potential indicators is guided by both a set of criteria for indicator selection and peer reviews of the decisions made in each phase; formal analyses, e.g., based on decision theory, may also be useful in helping identify the most effective suite of indicators for assessing wetland condition. The proposed indicator selection criteria for EMAP-Wetlands are listed in Table 4-1. As an indicator advances through the indicator development process, different criteria may be emphasized, the tests are expected to become more stringent, and more specific criteria will likely be developed. For example, literature evidence of responsiveness along laboratory or field exposure gradients is sufficient at the research stage, but quantitative evidence of responsiveness in most of the region's habitats may be required for an indicator to be considered developmental. An important component of this process is quantifying indicator variability, within sites, between sites, among wetland classes, and over time, based on existing data sets as well as the data collected in the pilot and regional demonstration projects. To be useful for EMAP-Wetlands, the natural, background variability for the indicator, as measured using the EMAP-Wetlands protocols during the index sampling period, must be sufficiently low to be able to detect regional patterns and trends through time of the magnitude, and with the level of confidence, necessary to achieve the program objectives.

The final phase is the implementation of core indicators at regional and national spatial scales. In this phase, it is important that a balance exist between **continuity** of methods to maximize trend detection capability

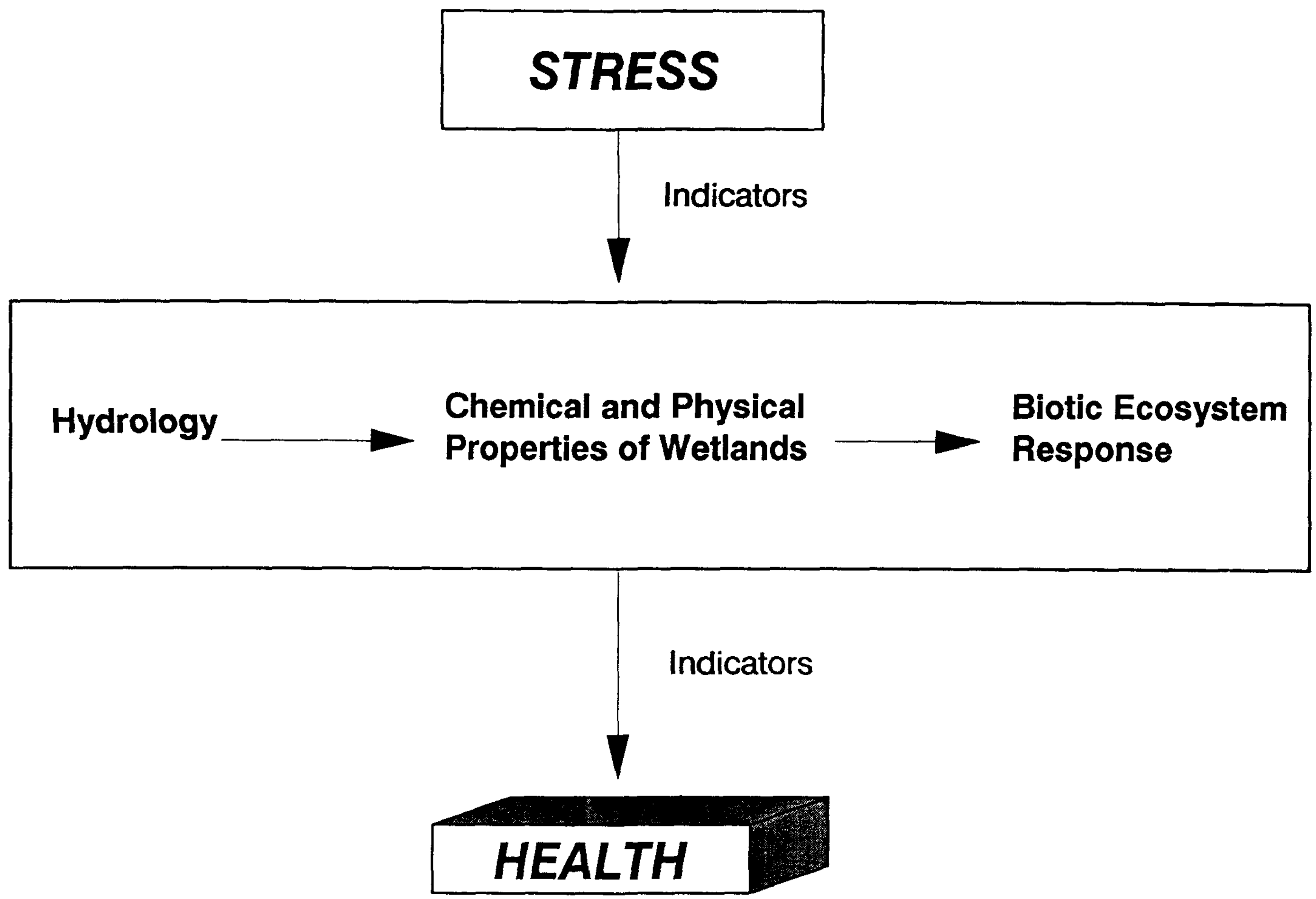

Figure 4-2. Conceptual diagram of wetland ecosystem and interpretation of wetland health.

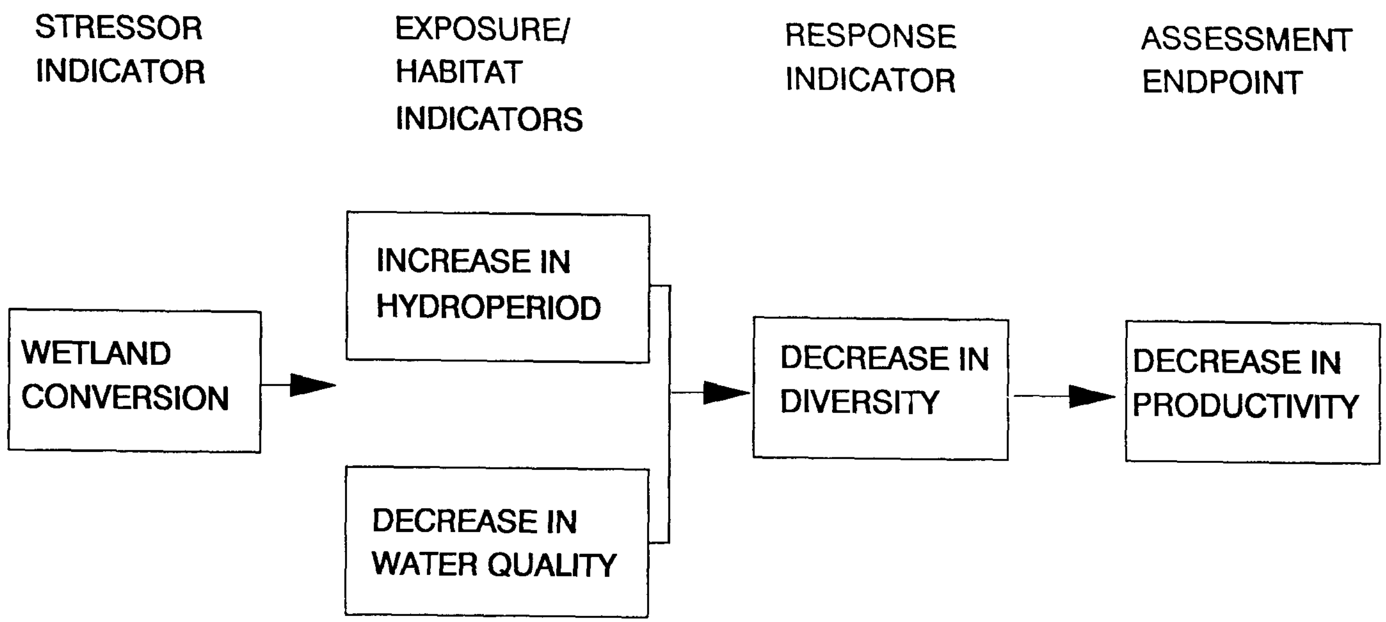

Figure 4-3. General conceptual model of wetland ecological condition linking a potential stressor to an assessment endpoint.

Table 4-1. Criteria Used to Select Candidate EMAP-Wetlands Indicators.

Responsive -	reflect change in ecosystem condition, and respond to either stressors of concern or management strategies
Regional Applicability -	applicable on a regional basis, and over a broad range of regional wetland classes
Unambiguous -	related unambiguously to an endpoint or relevant exposure or habitat variables
Integrates effects -	integrates ecosystem condition or stressors over time and space
Low natural variability -	exhibits low natural temporal and spatial variability at the sampling site during the index period to ensure detection of regional patterns and trends
Interpretability -	clear interpretation or ability to be related through conceptual models to either (1) meaningful changes in ecosystem structure and function or (2) changes in stresses affecting the ecosystem
Cost Effective -	low cost relative to information value

and **flexibility** to allow for continued indicator improvement. The latter will be achieved using a set of procedures that include critical review of the value of core indicators, substitution of superior indicators or sampling methods for some core indicators, research on promising candidate indicators, and re-examination of how well assessment endpoints are represented by the core suite of indicators.

Further details on the EMAP indicator development process are provided in Knapp et al. (1990), including plans for integrating indicator development and use among the EMAP resource groups.

4.2 EMAP-WETLANDS INDICATORS

Based on the findings of literature reviews and several workshops, the EMAP-Wetlands group together with EPA's Wetlands Research Program developed a list of potential candidate biotic and abiotic indicators for inland wetlands (Adamus and Brandt 1990, Leibowitz and Brown 1990). Following debate among staff and experts, this list of candidate indicators has been reduced to the current list of 10 proposed **research indicators** presented in this report (Tables 4-2 and 4-3). Two types of research indicators are identified. **High priority** research indicators are considered integrative measures of wetland condition or stressors, important wetland attributes, cost-effective to monitor, and thus ready for a pilot-scale field test and (or) indicator evaluation studies using existing data bases. It is expected that a full-scale, regional demonstration of these indicators could be implemented in the near future. **Low priority** research indicators, on the other hand, while they represent important wetland attributes, either do not provide an integrative measure of wetland condition or still require substantial research and development to (1) identify specific measurement techniques, (2) assess their utility for all regions, and/or (3) determine the magnitude of spatial and temporal variability. These low priority research indicators have the potential to be useful for EMAP-Wetlands, but must be investigated further before proceeding with extensive field tests.

Table 4-2. Candidate Wetland Indicators for EMAP.

Indicator	Category	Relevant Endpoints	Priority	Compatibility with Other Resource Groups
Wetland extent	Response & Exposure	S	High	High
Landscape indicators	Exposure & Response	S B	High	High
Indicators of Hydrology	Exposure	S P B	High	Low
Sediment Characteristics	Exposure & Response	S P	High	Low
Community composition and abundance of vegetation	Response	B P S	High	Moderate
Community composition and abundance of vertebrates	Response	B P		
Herpetofauna			Low	Moderate
Mammals			Low	Moderate
Birds			Low	Moderate
Community composition abundance of macroinvertebrates	Response	P B	Low	Low, except for adjoining surface water
Chemical contaminants sediment	Exposure	S	Low	Low, except for adjoining surface water
Bioaccumulation in tissues	Exposure	S B P	Low	Low
Nutrients in sediment and (or) vegetative tissues	Exposure	P S	Low	Moderate

S = Sustainability B = Biodiversity P = Productivity

Table 4-3. Sampling Protocols for EMAP-Wetland Indicators.

Indicator (Priority Order)	Suggested methods	Optimal Sampling Period/Frequency
Wetland extent	Aerial photos & satellite imagery	Growing Season
Landscape indicators	Aerial photos with field verification	Growing Season (leaf off for forests)
Indicators of Hydrology	Multiple staff gauges (PVC wells), soils, etc.	Growing Season
Sediment Characteristics	Substrate pads or disks	Growing season
Community composition and abundance of vegetation	Transect with random plots	Growing season
Community composition and abundance of vertebrates		
Herpetofauna	Timed searches	Spring
Mammals	Indicators of Presence/Absence	Growing season
Birds	Visual/auditory point counts	Breeding season
Community composition and abundance of macroinvertebrates	Benthic & water	Growing season
Chemical contaminants in sediment	Core samplers	Growing season
Bioaccumulation in tissues	Standard tissue analysis in selected species	1 - 4 years
Nutrients in sediment and (or) vegetative tissues	Standard water column and core samplers, and/or tissue samples	Growing season

For each of the proposed EMAP-Wetlands indicators, the following subsections provide background material; describe the rationale for indicator selection and a brief synopsis of the proposed approach for indicator sampling and measurement; and outline the remaining issues that must be resolved during indicator development and testing. As noted in Section 4.1, the list of proposed indicators is likely to change and be refined over time, based on additional interactions and workshops with experts; the results from analyses of existing data sets, field pilot studies, and regional demonstration projects; interactions with other EMAP resource groups; and the rapidly evolving literature (e.g. White et al. 1989). Additions, deletions, and modifications can be expected as field testing and evaluation progress. More specific proposals for indicator research and development are presented in Section 4.3. Issues related to indicator interpretation within EMAP-Wetlands are discussed in Section 6.

4.2.1 Wetland Extent

4.2.1.1 Description

Many functional attributes of wetlands are related directly to their size (areal extent). Remote sensing is the most effective way to monitor changes in wetland area over time. Analysis of trends data derived from aerial photography for the NWI has, to a great extent, provided the foundation for current public and private efforts to protect wetlands. Documenting losses and gains in wetland area are critical for understanding regional trends and identifying geographic areas in need of immediate attention. This response indicator is of fundamental importance to the monitoring program, as an important indicator of wetland sustainability.

4.2.1.2 Approach

The procedures available for remotely monitoring wetland size are compatible with the 4-year rotational scheme for Tier 2 sites proposed for EMAP-Wetlands. Remotely sensed data from aerial photographs (color-infrared film preferred) or satellite imagery (LANDSAT resolution is 30 m, SPOT is 10 m) will be transformed and entered into the Geographic Information System (GIS) developed for EMAP.

As discussed in Section 3.2, the acquisition of remotely sensed data on wetland area (extent) will be a joint effort between EMAP-Wetlands and USFWS's NWI. The NWI has produced over 30,000 wetland maps, covering approximately 65% of the Continental United States, 20% of Alaska, and all of Hawaii. Data on wetland extent, obtained from 1:40,000 to 1:80,000-scale aerial imagery, has been compiled, in most cases, onto 1:24,000 USGS quadrangle maps. NWI statewide digital databases have been built for New Jersey, Delaware, Illinois, Maryland, Washington, and Indiana and are in progress for Virginia and Minnesota. Digital NWI data are available for portions of 25 other states. As noted in Section 3.2, the updated NWI report to Congress on the status and trends in wetland extent and distribution, through the mid-1980s, has been completed and is in review. Regional, state, and local trend analyses by NWI and other sources are also available or underway for some areas of the nation (e.g. Tiner and Finn 1986, Frayer et al. 1989).

Variability in the characterization of wetlands using remotely sensed data, particularly aerial photography, can occur during the interpretation of imagery by different observers. NWI and their contractors use an established protocol to maintain quality control. Ground reconnaissance during scheduled sampling periods will be used to check the accuracy of a subset of the maps produced.

A second source of variability is the suitability and quality of aerial photographs with respect to seasonality, image quality, and the type of wetland evaluated. The size of many wetland areas changes significantly as a result of seasonal and annual variations in precipitation. Additional corroborating evidence, such as local climatological data (e.g., precipitation or stream gauging records), will be used to explain unexpected or unusually large changes in wetland area that might be attributed incorrectly to anthropogenic factors (see Section 6.2). The extent of forested wetlands can be difficult to assess through a leaf-covered canopy; thus, early spring photography is usually best. For most other vegetative communities, data collected during the growing season are preferred.

To date, NWI mapping has been conducted on about a 10-year cycle. Although analyses of wetland changes every 10 years may be sufficient to characterize gross national and regional trends, to be useful to EMAP-Wetlands it will be necessary to obtain additional aerial photography to coincide with the timing of the Tier 2 sampling. Given EMAP's proposed 4-year cycle for sampling Tier 2 sites, and the need for remotely sensed data for other resources (e.g., surface waters) not covered by the NWI, digitized data from LANDSAT or SPOT may be a cost-effective solution. In addition to the objectives cited above, these data bases may be used to provide temporal verification of selected wetland sites and updated information on land use. The multi-spectral bands available from satellite imagery might also be useful for assessing leaf area, greenness, and other landscape indicators, as discussed in Section 4.2.2.

4.2.1.3 Remaining Issues

The resolution of the aerial photography used for producing the majority of the NWI maps (1:40,000 to 1:80,000) limits the minimum wetland size that can be detected and monitored (generally wetlands < 0.5 ha are not visible). Clearly the technology exists to measure wetland area, although the differential costs and advantages of various scales and types of aerial photography and also satellite imagery must be determined. The initial data on wetland size, for the Tier 1 landscape characterization, will be obtained from existing NWI aerial photography and maps (Section 3.4). However, current plans are to obtain additional, low altitude aerial photographs (< 1:6,000 scale) for the Tier 2 sites (on a 4-year cycle), as discussed in Section 4.2.2.

4.2.2 Landscape Indicators

4.2.2.1 Description

A number of important wetland attributes, useful for assessing wetland condition, can be quantified remotely, using aerial photography and (or) satellite imagery. These indicators are referred to collectively as landscape indicators. Landscape indicators are of particular utility because (1) they may be more cost effective to measure than indicators that require field visits and (2) they generally provide an integrated assessment of wetland condition and stressors, more suitable for the scale of analyses (regional, long-term trends; see Figure 2-4) of interest for EMAP than are many of the more highly variable indicator measurements that can be obtained during field sampling.

A wide variety of landscape indicators may be potentially useful for EMAP-Wetlands. For example, interpretation of aerial photography (in particular low altitude aerial photography) and satellite imagery could provide information on

- wetland vegetation community composition;
- wetland edge patterns (retreats over time indicate filling or drainage; expansion suggests erosion or flooding);
- wetland open areas (an increase in open areas indicates more frequent flooding);
- occurrence and area covered by terrestrial vegetation (indicates less frequent flooding);
- greenness (an indicator of vegetative productivity and/or changes in vegetation community composition);

- o the occurrence and extent of sediment plumes (indicates nonpoint source pollution);
- o the occurrence and intensity of algal blooms (indicative of excessive nutrients); and
- o the occurrence and number of muskrat dens and beaver lodges and dams (indicates mammal activity).

Many of these landscape indicators, such as vegetation community composition, wetland edge patterns, and greenness, may be particularly useful for providing context for or corroborating data collected during field visits. For example, analyses of vegetation community composition from aerial imagery could be used to collaborate and explain vegetation transect data collected on the ground (see Section 4.2.5). Changes in herbaceous plant community structure (as measured by both remote sensing platforms and field measures) generally occur rapidly in response to stress (e.g., drought, eutrophication, contamination). Canopy closure (solar transmittance) and photosynthetic potential (leaf area and greenness) are indicators of vegetative responses to stressors that cause decreases in primary production or increases in respiration. A reduction in canopy coverage or decrease in greenness may indicate the onset of a stress response before permanent compositional changes occur.

The characterization of spatial patterns, both within and outside of wetland boundaries, provides a measure of habitat and landscape structure, which in turn influences ecological functions, particularly animal diversity and abundance. The availability of habitat patches of sufficient size and the degree of connectivity among patches via corridors affect the types of species that can be supported. The importance of habitat fragmentation is well documented for birds (Robbins et al. 1989, Gosselink et al. 1990). Thus, correlations between vertebrate response indicators and the results of spatial pattern analyses will be particularly relevant.

Numerous indicators of spatial patterns have been suggested (see O'Neill et al. 1988 and Turner 1989) although relatively few have received rigorous empirical scrutiny. Some indicators describe landscape heterogeneity as a function of patch characteristics. Others emphasize the arrangement of patches. However, in all instances, the choice of scale is critical to the measurement and interpretation of pattern indicators. For EMAP-Wetlands, two categories of scale are appropriate. Within individual wetlands selected for monitoring, patch areas will range typically from 0.1 to 10 ha, whereas patches measured in a landscape context will range from 10 to 1,000 ha. Analyses of these two scale categories will remain independent, although scales may occasionally overlap.

4.2.2.2 Approach

For each Tier 2 wetland sampling unit, low altitude aerial photography (< 1:6,000 scale, color infrared preferred) will be obtained from existing sources, if available, or by acquiring new photographs. These photographs, plus other remotely sensed data (e.g., high resolution data from SPOT or LANDSAT), will be used to characterize each of the landscape indicators discussed in Section 4.2.2.1. The specific techniques for photointerpretation and data interpretation will be refined and tested (through groundtruthing) during field pilot and regional demonstration studies. The combined set of indicators will provide direct and indirect measures of changes in vegetation composition and productivity, shifts in hydrology and the frequency of flooding, nonpoint discharges of sediment and nutrients, and recent encroachments on or physical alterations to the wetland. Together with the field data collected at each site, the data obtained from remote sensing provide the potential for distinguishing among major impacts on wetland systems, such as dredge and fill operations, drought, flooding, beaver impoundments, and natural succession (e.g., Golet and Parkhurst 1981).

The following measures of landscape spatial patterns are proposed for use in initial trials, although others may be equally suitable. The most common metric for assessing landscape pattern is land use. Using a land use classification system, such as the one devised by Anderson et al. (1976; Levels II or III recommended), the area or proportion of each land use type is determined. Based on an assessment of impacts for a given region, the ratio of disturbed to undisturbed types can be computed. Higher ratio values indicate more disturbed landscapes or wetlands.

These same land use types can be used to categorize patches, but attention must be paid to the scale of the source data (Fitzpatrick-Lins 1980). The number of patches can be characterized graphically using frequency distributions of areas (log normal scale suggested; Gosselink and Lee 1989). The shape of an individual patch can be described by a perimeter-to-area ratio (the more varied the outer boundary, the higher the value), whereas characteristic shapes for a group of patches are best defined by calculating fractal dimensions. If the landscape is composed of simple geometric shapes, such as farm fields or house lots, the fractal dimension will be small, approaching one. If the landscape contains more convoluted shapes, where the perimeter-to-edge ratio is high, the fractal dimension will be much greater than one. The fractal dimension is estimated by regressing the logarithm of the polygon perimeter as the dependent variable against the logarithm of the area for all patches as the independent variable. The fractal dimension, F, is equal to two times the slope of the regression, S (Lovejoy 1982):

$$F = 2S$$

The arrangement of patches is critical to the movement of organisms across a landscape, and thus critical to the maintenance of biodiversity. Patch arrangement is often characterized by the amount of linear edge (km/km^2) per unit area of landscape. Edges, as defined by the juxtaposition of two different land use types, are measured and then tallied. It is important to distinguish between edges formed along expected environmental gradients, such as bands of vegetation along a moisture gradient, versus edges considered to be a negative result of human activities (e.g., utility corridors, agricultural fields). Edges can be categorized simply into undisturbed and disturbed types.

Contagion is a landscape index derived from information theory (Shannon and Weaver 1962) that also describes the arrangement of patches. It is a measure of the probability of patches being adjacent to each other (O'Neill et al. 1988). The recommended formula that is relatively independent of the number of land use types is:

$$C = \sum_{i=1}^{n} i \sum_{i=1}^{n} i \ P_{ij} \ \ln(P_{ij}) \ / \ n \ln(n)$$

where P_{ij} is the probability of a point of land use i being found adjacent to a point of land use j. The term, n ln(n), represents a maximum in which all adjacency probabilities are equal. For both edge and contagion, higher values indicate landscapes where a more heterogeneous condition prevails and where patches are highly interspersed.

4.2.2.3 Remaining Issues

Landscape indicators are considered to be both important and feasible indicators of wetland condition, especially when complemented by the groundtruthing and measuring additional indicators during field sampling at each Tier 2 site. However, further analyses are needed to determine the most appropriate and cost-effective scales and types of aerial photography and (or) satellite imagery to be used, given the objectives and constraints of EMAP-Wetlands. In addition, the relative costs and advantages of gathering data through remote sensing versus field sampling must be evaluated, to determine the optimal distribution of funds and effort. Initial cost estimates suggest that between $500,000 and $2,250,000 may be required to provide aerial photography for each Tier 2 site once every four years. The lower end of this cost range may be achieved through economies of scale and contracting for photography at multiple sites.

Although greenness and other indicators of vegetative response may add an important dimension to the analysis of remotely sensed data, many of these measures need further examination and testing before they can be implemented as indicators of wetland condition. Greenness can be measured as light reflectance in visible bands (and sometimes infrared bands) from satellite imagery. Natural variations in greenness, both temporally and spatially, are expected to be extremely high within most wetland classes, but may still yield valuable information when viewed from a landscape perspective using remote imagery. Absolute threshold values of greenness that represent responses to stress or subnominal condition are not known. Thus, reference sites would be essential for interpreting the monitoring results (Leibowitz and Brown 1990). The relationship of greenness to ecological stress has been used with success in monitoring agricultural crops; greenness may also be used as an indicator of leaf area in forested wetlands and as an indicator of coverage in herbaceous wetlands.

Analysis of landscape pattern can easily be made using the GIS. However, further investigations are needed on the effect of scale on measures of spatial patterns (Wiens 1989). Some landscape indices developed recently deserve further testing in pilot studies as they may be useful for identifying cumulative effects or increases in urbanization [the Synoptic Approach developed by Abbruzzese et al. (submitted) and Land Development Index developed by Brown et al., submitted,] within and surrounding EMAP hexagons. Evaluating the relationship between landscape heterogeneity and wetland sustainability and integrity should be a primary objective of EMAP pilot studies. Strong correlations between measures for this indicator and others should be examined closely to reveal potential causal relationships.

4.2.3 Indicators of Hydrology

4.2.3.1 Description

Hydrology is the major forcing function regulating wetland health. By definition, the source and periodicity of water determines the structural and functional characteristics of every wetland and, hence, its sustainability, productivity, and biodiversity, (Mitsch and Gosselink 1986, Brinson 1988). Changes in wetland hydrology are probably the most common impact associated with human activities on the landscape. When the hydrology is altered, changes in nearly all other abiotic and biotic components of a wetland can be expected. The processes that define a wetland may shift dramatically or imperceptibly. Soil characteristics and nutrient fluxes will be affected. The capacity for a wetland to store water, and to retain sediment and contaminants can be altered. Species composition of floral and faunal communities can be expected to change, as well as wetland productivity. In essence, the fate of a wetland is tied directly to the fate of the surface and ground waters that support it. Although hydrology is of recognized intrinsic importance to a wetland, its measurement can be somewhat elusive. The measurements proposed below, therefore, are indicators of wetland hydrology, which when combined with accessory information (e.g., continuous monitoring data at USGS stream gauges and groundwater wells, information on regional water balances) can provide an adequate assessment of the hydrologic regime at each Tier 2 site given the long-term temporal and regional spatial scales of interest for EMAP-Wetlands.

4.2.3.2 Approach

Monitoring water levels continuously in wetlands would be optimum; periodic measurements from staff gauges or observation wells would be adequate. However, because of the constraints of the EMAP protocol (one-day visit during an index period) neither of these is practical at all sampled sites. Therefore, the proposed approach for assessing wetland hydrology for EMAP-Wetlands is as follows:

- o A small subset of the Tier 2 sites (plus selected reference sites) will be equipped with devices to record water levels continuously and that will function, unattended, for four or more years. These devices will be strategically located within or near the wetland to provide the most useful information on water levels as they may affect the wetland. They will be anchored below the frost line and periodically surveyed to assure that the data collected will be valid and comparable throughout the period of record, as well as comparable to off-site gauges, e.g., at nearby USGS gauging stations.

- Other wetlands, again a small representative subset of the Tier 2 sample, will be instrumented with water level recording devices that record the highest and lowest water levels occurring between visits.

- At all of the Tier 2 sites, at the time of the Tier 2 field sampling, water levels will be determined (both above and below the wetland surface) at several locations within the wetland and related to the wetland surface elevation. The time of each measurement will be precisely noted, and these data will later be compared to water levels recorded at nearby stream gauges, observation wells, or tide gauges, as appropriate (Novitzki 1979b, Riggs 1969). Where possible, water levels at surface water gauges, observation wells, or tide gauges at the Tier 2 sites will be periodically or continuously recorded for up to 24 hours.

- A variety of indirect indicators of wetland hydrology will also be measured during field sampling at each Tier 2 site, including the bulk density and organic matter content of the soil, peat depth, carbon to nitrogen ratios in the soil, and sedimentation rates. Each of these indicators are wetland soil attributes which integrate and reflect the long-term hydrologic regime and flooding frequency at the site. For example, organic soils tend to accumulate in wetter areas; hence, thick undecomposed (fibric) organic soils indicate a higher degree of soil wetness than do either decomposed organic soils or mineral soils. To interpret these indirect indicators will require, however, (1) an understanding of other factors that influence soil characteristics (e.g., vegetation community type) and (2) quantitative information on the relationship between soil characteristics and wetland hydrology, derived from reference sites and the continuously monitored subset of EMAP Tier 2 wetlands. Further discussion on the methods for measuring and interpreting these indirect indicators of hydrology is provided in Section 4.2.4.

- Finally, data collected through remote sensing, as described in Section 4.2.2, also will provide insight into the wetland hydrological regime (e.g., changes in the frequency of flooding reflected in a shift in the proportion of open water).

By relating the instantaneous water level measurements and indirect indicators of wetland hydrology to the long-term water level records at some Tier 2 sites and also to other sources of information on short- and long-term hydrologic fluctuations in the area (e.g., USGS gauging stations), these data sets should provide sufficient information to assess the approximate depth, frequency, and duration of flooding at each Tier 2 site, as well as the severity and duration of dry periods. Leibowitz et al. (1988), for example, used historical stream gauging records and future projected trends in stream discharge to evaluate regional hydrologic trends for wetland resources in basin-wide studies.

One method being considered to help interpret the hydrologic data collected is to relate measures of soil moisture, taken at each site during the Tier 2 field sampling, to some regional norm, such as a regional water balance value calculated using the techniques suggested by Thornwaite or Penman (e.g., Thornwaite and Mather 1957), or by developing a soil moisture index that could be compared to the Palmer Drought Severity Index (Palmer 1965). Sites with a soil moisture level significantly higher than expected, relative to the regional norm, would likely be areas that receive ground water discharge. This kind of insight, concerning the hydrologic setting of the wetland, is needed to better interpret and explain the stressors and cause-and-effect relationships that may affect wetland condition.

Another useful measure of wetland hydrology, that may complement the data described above, is the determination of discrete inflows and outflows into the wetland at the time of the sampling visit. EMAP-Wetlands proposes to monitor these parameters using relatively simple and inexpensive measurement techniques, such as by measuring water velocity and channel cross sections to estimate discharge. These instantaneous measures of wetland discharge can then be related to available long-term stream gauging records, as discussed above, to better define the hydrology of the site. More accurate information on wetland inflows and outflows could be obtained using continuous recorders attached to weirs or flumes, which could be monitored by state personnel or the research community. Flow and discharge measures can only be collected for wetlands with discrete inlets outlets.

4.2.3.3 Remaining Issues

The importance and interpretation of hydrology as an indicator of wetland condition are straightforward. It would be costly and difficult, however, to collect meaningful direct measurements of wetland hydrology at each Tier 2 site, because of its large temporal variability. By correlating the proposed indicators of hydrology with local climatological information and continuous water level records at stream gauges, tide gauges, and ground water wells, the data collected may be more accurately interpreted and of greater value. Field observations and aerial photography, if carefully coordinated, can be used to define the maximum and minimum extent of flooding in and around wetlands, providing a check against hydrologic measurements made in the field. All of the above proposed indicators require, however, further field testing and calibration before they can be implemented and interpreted with confidence for EMAP-Wetlands. Additional studies are also needed to understand the relationships between water level fluctuations occurring in streams, lakes, and reservoirs and those occurring in wetlands.

4.2.4 Sediment Characteristics

4.2.4.1 Description

When viewed from a watershed perspective, wetlands typically function as relatively small pockets of accretion on an otherwise eroding landscape (Brinson 1988). From a geophysical perspective, wetlands are depositional landforms, even though during some seasons certain materials may be exported. If the rate of sediment flux within a wetland can be monitored accurately, then changes in an established trend could be detected and serve as an indicator of disturbance, as well as wetland sustainability and productivity. However, sedimentation in wetlands is relatively modest when compared to landscape-level subsidence rates (Brinson 1988).

Flux rates for sediment and organic matter have not been measured on a regional basis in wetlands. The reported rates from individual studies are disparate, with riparian wetlands accreting 0.8 to 2.8 cm of sediment per year (cm/yr) (Bridge and Leeder 1979) and lacustrine wetlands ranging from 0.6 to 14.1 cm/yr (Ritchie 1989). Organic matter accumulates more slowly, with typical rates being 0.06 to 0.20 cm/yr for temperate wetlands in the United States (Ritchie 1989).

High rates of sedimentation may have adverse effects in some types of wetlands, rapidly decreasing wetland size and condition, but may be beneficial in others. For example, for some coastal marshes, high rates of sediment input are required to counter the effects of land subsidence. Changes in sediment and organic matter flux rates may be indicative of a number of wetland stressors. Mulholland and Elwood (1982), for example, found that the accumulation rate of organic carbon was higher in small lakes and culturally eutrophic lakes than in oligotrophic lakes. The interpretation of regional data on sediment and organic matter fluxes must be coordinated carefully with data on changes in the spatial patterns of landscapes and individual wetlands (Section 4.2.2), if the anticipated rate variations and causal factors are to be addressed.

Measures of sediment characteristics also provide important information about wetland hydrology (see Section 4.2.3) and sustainability. Soil bulk density is defined as the weight of the soil divided by its volume (including both soil particles and the pore space) and therefore is a good measure of soil structure (Blake 1965). It also covaries with both inorganic matter and water content (Rainey 1979). Soil organic matter content is directly related to bulk density by the following equation (Gosselink et al. 1984):

$$\text{bulk density} = 100\ K\ /\ \text{organic matter content}$$

In flooded soils, K is the mean organic carbon density of the soil as defined by volume-based data, i.e., carbon density in grams of dry organic mass per milliliter of wet soil volume (Gosselink et al. 1984). Generally, the wetter the area, the higher the organic matter of the soil, because wetness inhibits decomposition of plant material more than it inhibits plant growth. A measurement of organic carbon in the soil profile might provide, therefore, a baseline for assessing the effect of either increases or decreases in wetness (see Section 4.2.3). Carbon to nitrogen (C/N) ratios in soils also provide an indirect measure of hydrology, with high ratios being related to wetter conditions.

4.2.4.2 Approach

Of the numerous techniques available for measuring sediment flux, those best suited to the EMAP design and protocols involve placing artificial surfaces on top of and into the existing substrate, and returning at a later date to measure and retrieve the sediment that accumulates during the sampling period. Annual sampling is usually recommended, although longer periods of accumulation may also be used. EMAP sampling will occur at each site once every four years. Surfaces will be created using feldspar clay pads, typically 0.25 m^2 (Cahoon and Turner 1989). The pads function best if deposited and measured when substrates are not inundated (Barb Kleiss, U.S. Army Corps of Engineers, pers. comm.). Another simple, but effective, technique involves placing white plexiglass disks, 15 cm in diameter, into the substrate. The disks are bolted to metal rods to keep them in place (brass, threaded at one end; Barb Kleiss, U.S. Army Corps of Engineers, pers. comm.). The surfaces of the disks are roughened to facilitate sediment adhesion. The metal anchoring rods also help field crews locate buried plates with the aid of metal detectors. If necessary, larger surfaces can be created using plaster platforms. Either material is sufficiently inert to last 5 or more years.

The location of each sampler will be carefully marked in the field and on site maps. By locating samplers a set distance from PVC pipes or other devices used to investigate hydrology, they can be found more easily year to year. Also, the hydrologic data can be correlated with the results of sediment studies.

The above techniques will work for accretion studies, but measurement of erosion rates is more difficult. The removal of mineral or organic materials must be calibrated against a known reference point, such as the clay pads and (or) PVC pipe. Additional research is needed to develop a suitable technique for quantifying erosion rates in wetlands for EMAP.

Composite soil samples will be measured for important sediment characteristics (e.g., textural, elemental, contaminant). Current plans are to measure organic depth, bulk density, organic matter content, and C/N ratios in the soils; chemical contaminants (Section 4.2.8) and nutrients (Section 4.2.10) in sediments will also be measured, although not necessarily in conjunction with the measures of sediment flux. Since organic matter generally accretes at slower rates than sediment, bulk density and organic matter sampling could occur less frequently. The proportion of organic matter accumulating can be determined by measuring the detritus that collects over mineral components, and by burning off the fine organic material mixed in with mineral particles. At a minimum, three (> 6 recommended) sampling devices will be installed along each of the transects established for vegetation and vertebrate indicators (see Section 4.2.5). Samples will be weighed and oven dried (~90°C) to a constant mass to determine percent water and bulk density. C/N ratios will be determined in both the organic layer and accreting sediments.

4.2.4.3 Remaining Issues

In designing the field sampling program, the effort required to account for spatial variations in sediment characteristics must be balanced against the potentially prohibitive analytical costs of taking numerous samples. Samples may, however, be composited for analysis, to control costs while still allowing for relatively large numbers of spatially distributed sampling locations. The sediment pads provide logical points for sampling contaminants and nutrients that may have accumulated in the wetlands or at least moved during the sampling period. Chemical analyses could be conducted on composite samples after depth measurements are taken. Studies on both reference and disturbed wetlands are needed to develop expected flux rates under a variety of environmental conditions before threshold values, associated with disturbance or altered wetland condition, can be determined. Based on a literature review, the measurement of accretion for mineral sediments appears to be more straightforward than for organic matter.

4.2.5 Community Composition and Abundance of Vegetation

4.2.5.1 Description

Vegetation is the primary means by which wetlands are described and classified (Cowardin et al. 1979). Thus, measures of vegetation community composition and abundance are considered high priority indicators for EMAP-Wetlands. Changes in plant communities are intimately tied to all of the proposed EMAP-Wetlands assessment endpoints: sustainability, biodiversity, and productivity. Studies of vascular plant communities and their characteristics are abundant in the literature, and sampling methods are well developed (Britton and Greeson 1988, Frederickson and Reid 1988). Wetland plants, because they are immobile, are reliable indicators of certain types of stressors, such as changes in hydrology and nutrient/pollutant loadings (Leibowitz and Brown 1990). The composition and density of herbaceous communities and the forest understory will respond readily to short-term impacts. Tree and shrub species, on the other hand, are better indicators of long-term stressors. The methods suggested here were chosen for their simplicity, application to a wide range of ecosystems, and potential compatibility with community-based metrics that may be developed in the future. Changes in the community composition or density of vegetation should coincide with the coarser indicators of spatial pattern (Section 4.2.2).

4.2.5.2 Approach

Wetland plant communities are commonly assessed by describing their floristics (species lists), vertical structure (life form, layers), and horizontal arrangement (coverage, density). The types of metrics being considered for EMAP-Wetlands include

- o the occurrence of wetland indicator species,
- o the weighted average ratio of wetland obligate to facultative species (discussed further below),
- o the occurrence of species considered tolerant or intolerant of anthropogenic stressors,
- o the ratio of percent occurrence of exotics to native species,
- o species composition,
- o species dominance,
- o percent vegetation cover,
- o vegetation height (e.g., for trees and salt marshes), and
- o vegetation density and age, in particular for wetland trees.

The following sampling protocol is tentatively proposed for vegetation sampling in EMAP-Wetlands. Field pilot studies will be conducted to finalize sampling methods and resolve questions about the applicability of some of the measurement techniques for a range of wetland classes in different regions (see Section 4.3.2) and also the sensitivity of the metrics proposed above for assessing wetland health.

Within individual wetlands, permanent transects will be established in each major plant community identified from remotely sensed data (Anderson et al. 1976, Level II). Transects will be oriented parallel to hydrologic or other relevant gradients within each community. Beginning and ending points will be marked precisely on the site map and marked on the ground with iron rods. Plots will be located randomly along the transect, but spaced at 10-m intervals or greater to avoid overlap.

The number and length of transects will depend on the shape, orientation, hydrologic gradients, and interspersion of plant communities. The minimum length for transects is usually 100 m, but the selected distance will be based on the size and shape of the plant community. Current plans are to sample three, 100-m transects as an index of vegetation in discrete wetlands. In large, homogeneous wetlands, cluster sampling techniques are proposed (see Section 5).

The locations of major transitions in wetland class (see Appendix B) along transects will be noted. Similarly, the location of each plot in relation to major plant communities (e.g., herbaceous, shrub, forest) will be recorded. These data will enable analysts to associate the occurrence of individual species with distinct classes and (or) communities. Shifts in plant communities over time can also be determined, assuming that the same transects are used in subsequent field work.

One promising technique to evaluate changes and differences in plant communities is the use of Weighted Averages (WA, e.g., Wentworth et al. 1988, Allen et al. 1989, Brown et al., submitted). The degree of wetland dependency for vascular plants, as assigned by the USFWS (Reed 1988), can be converted to a scale from 1.0 (obligate wetland) to 5.0 (obligate upland). Data from individual sample plots are ranked and then correlated to the transect which passes through major plant communities, and presumably has been oriented parallel to the primary hydrologic gradient in the wetland. Long-term shifts in the composition and position of plant communities in each wetland should reflect cumulative impacts to the system, particularly as a result of changes in wetland hydrology.

For plots in herbaceous vegetation, 1 m^2 square or rectangular (2:1) quadrants are the standard, although microplots (which are preferred for grass-like plots) also may be used (Federal Interagency Committee for Wetland Delineation 1989). The number of quadrats sampled will depend on how species are interspersed within the wetland. One approach is to construct a species area curve; quadrats are added until the curve begins to level off (Federal Interagency Committee for Wetland Delineation 1989). A minimum of 8 quadrats/transect is proposed. For each plot, a species list will be developed. To provide consistency nationwide, common names, scientific names, indicator status, and stratum designation will follow the regional lists of wetland plants developed by NWI (Reed 1988). Major bryophyte species will also be noted. Plant identification will be done in the field whenever possible to avoid destructive sampling. The percent of the plot occupied by each dominant species will be estimated as a measure of coverage. Due to their high variability, labor-intensive sampling techniques, such as stem counts, biomass determinations, productivity, and decomposition studies, are not recommended. Sampling of herbaceous communities will occur during the growing season (see Section 5), preferably during the latter half when the majority of species have produced flowers and/or fruit.

Shrubs, saplings, and vines will be sampled in a circular plot with a 9-meter (30-foot) radius centered on the transect [0.025 ha (0.065 acre) in area]. This plot size corresponds to that recommended in the federal wetland delineation manual (Federal Interagency Committee for Wetland Delineation 1989), thus providing some standardization throughout the United States. Coverage for each individual plant (or multi-stemmed clump) will be estimated by taking the diameter of the maximum extent of foliage and assuming a circular outline. Percent coverage by species can be calculated from these data.

Trees may be sampled using the plotless method of determining basal area with a prism or angle gauge, both within the 9-meter circular plot and extending beyond its perimeter (Federal Interagency Committee for Wetland Delineation 1989). The basal area factor appropriate for each region or forest type will be used and the basal area computed for each tree. Species will be tallied using the NWI plant list nomenclature. Sampling for shrubs and trees can be done in the dormant season, but the growing season is preferred. The relative dominance of species in each vegetative stratum can be determined from the proposed measurements.

The procedures proposed above for sampling wetland vegetation may not be appropriate in all regions or for other EMAP resources. It may be desirable to have the vegetation sampling strategy for EMAP-Wetlands conform to an overall vegetation sampling strategy for all EMAP resource groups. At a minimum, the methods selected for forested wetlands will be closely coordinated with those used by EMAP-Forests. For example, the indicators and methods used to sample forested wetlands will be similar if not identical to those used by the EMAP-Forests group. Examples of alternative sampling methods that could be used include nested 2:1 rectangles for herbs (1 m^2), shrubs (10 m^2), and trees (100 m^2)(Brower and Zar 1984) and 20 x 50 cm microplots for herbs, a 2:1 rectangle (50 m^2) for riparian shrubs, and 375 or 500 m^2 plot for trees in the western United States (Platts et al. 1987).

Permanent photographic stations will be established in representative vegetation community types within each wetland, perhaps associated with the metal rods used to mark the beginning and end of transects. The direction and angle of view will be carefully noted. Photographs will document the general appearance and extent of the vegetation and will assist future workers in locating sampling points.

4.2.5.3 Remaining Issues

Compositional changes in wetland plant communities in response to fluctuating water levels have been a basic tenet of managing waterfowl impoundments for decades (e.g., Knighton 1985). More recently, Zimmerman (1988) characterized wetlands based on their response to variable hydrology. Adamus and Brandt (1990) reviewed the literature on how wetland vegetation responds to a variety of water quality stressors. They were able to identify numerous studies where species could be categorized according to their response to specific stressors. Yet, there is no single analytical method that can be used to predict how wetland plants will respond to changing environmental conditions. Indices, such as the Flood Tolerance Index (Theriot and Sanders 1986) and the Wetland Site Index (Michner 1983), are indicative of the potential for developing community-based metrics. Ratios of sensitive to common species, or exotics to native species show promising results (Brooks and Croonquist, unpublished). Given the abundant (but disjunct) literature concerning wetland vegetation, it may be possible to summarize the expected responses of individual species to various environmental stressors on a regional basis. This information could be molded into a community-based metric for comparison to the species lists and data on relative abundance that will be collected for EMAP. The combination of data on floristics, relative abundance, and spatial pattern that will be collected for individual wetlands might be coupled with hydrologic and water quality data to reveal predictable and measurable responses to changing wetland conditions. The collection of vegetative data proposed here will be useful, even though development of community metrics and our understanding of direct cause and effect relationships need further research.

4.2.6 Community Composition and Abundance of Vertebrates

4.2.6.1 Description

The types of habitat required to meet the life requisites of vertebrate species have been extensively documented. Thus, vertebrates are often considered to be useful indicators of how environmental conditions are changing within those habitats. Vertebrates can serve as integrators of cumulative impacts, because they are often the trophic end points of a biological continuum that is exposed continuously to a broad range of negative effects. As a result, vertebrates are useful indicators of biodiversity for many faunal taxa. Most vertebrate taxa are of major interest to the public, either because of their commercial value (e.g., hunting and fishing) or because they are readily observable (e.g., birding) (Brooks and Hughes 1988). Therefore, vertebrate species are seen as logical candidates for EMAP's suite of response indicators. Yet, the empirical basis for predicting how vertebrates will respond to environmental impacts in wetlands is weak. The evidence is best for toxicity testing on single, aquatic species; only one community-based index (the Index of Biotic Integrity for fish; (Karr 1981, Karr et al. 1986) has been widely applied and tested on a regional basis. Recent research has shown that monitoring vertebrate species and communities can be an effective way to evaluate changing environments [Karr 1987, Brooks et al. in press(a), Root 1990], if precise definitions and procedures are used to specify the rationale, goals, and context for monitoring a particular taxa (Landres et al. 1988).

Vertebrates selected as EMAP-Wetlands indicators should be wetland dependent (at least for a portion of their life cycle), broadly distributed, relatively easy to observe and measure, and sensitive to habitat modifications associated with expected stressors. Unfortunately most vertebrates do not meet these criteria.

4.2.6.2 Approach

Sampling methods for vertebrates of potential utility for EMAP-Wetlands are presented by major taxonomic group: fish, herpetofauna (reptiles and amphibians), mammals, and birds.

Fish. The life histories of many fish species are well known, and sampling methodologies have been thoroughly developed. Fish are absent, however, from most types of wetlands, and therefore are a poor choice as an indicator of wetland condition. For wetlands that occupy the fringes of deeper waterbodies and rivers, it is assumed that the biological sampling conducted by EMAP-Surface Waters and EMAP-Near Coastal will include fish communities. Fish communities may be sampled directly, for community composition and (or) bioaccumulation of contaminants, and also are suitable response organisms for toxicity tests.

Herpetofauna. The long life span of some reptiles, such as turtles, and the sensitivity of many amphibians to water pollution make them likely candidates for inclusion in a monitoring program (e.g., Phillips 1990). Arrays of pitfall traps and drift fences have been recommended as the best means of sampling herpetofauna (Vogt and Hines 1982). However, successful trapping programs are dependent upon narrow seasonal windows (usually a few weeks during spring and fall) and multiple trap nights, and thus would be difficult to implement given the logistical constraints imposed by the EMAP design (see Section 2.1). Brooks and Croonquist (Pennsylvania State University, pers. comm.) found that timed searches for herpetofauna yielded a consistent number of species and were more efficient than trapping programs. This would allow inclusion of herpetiles in a one-day sampling program. Still, for most regions of the United States, herpetofaunal communities may be too small and elusive to give comparable results across a broad spectrum of wetlands. Thus, these indicators are considered of low priority (i.e., requiring further methods development) for field testing within EMAP-Wetlands at this time. To accommodate the need for amphibian sampling during times other than the proposed EMAP-Wetlands index period (mid-growing season; see Section 5), a statistical subset of the EMAP-Wetlands Tier 2 sites may be sampled during the early spring to identify mating amphibian species.

Another possible approach would be to monitor amphibians as indicators of the presence of chemical contaminants. In particular, introduced organisms (using species that occur within that wetland type), constrained in cages, would provide a more uniform, standardized methodology for comparing among systems (i.e., reference sites versus disturbed wetlands). Recent research has shown that bullfrogs are highly sensitive to chemical contaminants, as evidenced by chromosomal aberrations. In situ bioassays with bullfrogs, placing them in wetlands for fairly short periods of time, could result in potentially useful data for assessing wetland health. However, such studies would require a return trip, to retrieve the caged specimens, adding to the cost and effort of the EMAP-Wetlands sampling. The feasibility and effectiveness of using introduced organisms as response or exposure indicators are being explored.

Mammals. Many mammalian species are nocturnal, and those with diurnal habits are elusive. Sampling for mammals requires the use of several trapping techniques, involving a variety of capture devices and multiple trap nights. Despite the use of an extensive trapping program for small mammals, medium and large carnivores, and bats, Brooks et al. [in press(a)] and Croonquist (1990) found only weak correlations between the occurrence of mammals and the variable levels of disturbance affecting wetland and riparian areas. Many mammalian species are adaptable to habitat alterations, and only a few species are sensitive to the negative impacts that threaten aquatic systems.

The presence and absence of mammalian carnivores, which occupy the higher trophic levels, may serve as warning signs that habitat conditions or pollutant loads are reaching critical levels. However, the amount of effort needed to detect most carnivores may not be cost-effective. Muskrat dens are fairly easy to detect using aerial photography (see Section 4.2.2). In addition, the muskrat is one of the best examples of a wetland dependent animal. The species, however, is tolerant of even drastic habitat modifications and, therefore, of little value as an indicator of wetland condition. The composition and demographics of small mammal communities have been studied extensively; however, the standard sampling procedure of placing traps in a grid pattern over a period of several days is time consuming. Intensive sampling is required to account for the high variability in small mammal abundance. Furthermore, there is little evidence to suggest that either abundance or community composition of small mammals varies predictively in wetlands exposed to differential impacts. Thus, additional field studies are needed to determine if mammals will satisfy EMAP's criteria for wetland indicators. Until further research is completed, certain mammalian groups will be targeted only when specific kinds of impacts are suspected. Tissue samples from ubiquitous species of small mammals, harvested game species, and furbearers might be a useful component of bioaccumulation studies (see Section 4.2.9). In addition, readily identifiable indicators of mammal presence, such as beaver lodges or the presence of scats or tracks, would require relatively little added effort during field sampling, and thus will likely be included in the EMAP-Wetlands Tier 2 sampling protocols.

Birds. If vertebrate diversity is to be used as an EMAP-Wetlands indicator, then birds are the most likely candidates. Birds are recognized by the public as interesting and essential components of ecosystems, they are easily identified and monitored, and their responses to various types of stressors are fairly well known. The mobility of birds makes them sensitive to cumulative, regional effects that may be altering the extent and diversity of wetland types. Initial efforts to protect wetlands were tied directly to declining populations of waterfowl and waterbirds in the early 1900s. Public interest in birds remains intense. The availability of historical data bases throughout most regions of the United States, such as the Breeding Bird Survey (BBS), Breeding Bird Censuses (BBC), Christmas Bird Counts (CBC), and state breeding bird atlases (BBA), provides a benchmark for future monitoring. Birds can be used to integrate changes across EMAP resource groups, and the availability of volunteer surveys (BBS, CBC, birding clubs, USFWS waterfowl and woodcock surveys) can add information inexpensively to the EMAP-Wetlands data base. Finally, given the interest in biodiversity as an assessment endpoint, some faunal measure is needed to adequately assess biotic communities.

One or more of the standard protocols for avian censuses will be used to sample the major habitat types found in each of the Tier 2 wetlands. Random, 5-minute point counts on plots (25-m radius, 0.2 ha/plot) located at 50-m intervals along transects (minimum length of 100 m) or at selected vegetation plots (spaced at least 50 m apart) are tentatively proposed. Sampling will be conducted in the early morning hours, and ideally should occur during the breeding season, which typically is early in the growing season. Trained observers will record the occurrence and relative abundance of bird species, based on visual and auditory cues (Conner and Dickson 1980, Mikol 1980, Croonquist 1990). From these data, diversity indices (Krebs 1989) and guild analyses (e.g., Short 1984, DeGraff et al. 1985, Brooks and Croonquist in press) can be extracted. Preferably, sites would be sampled more than once per year; thus additional sampling during spring or fall migrations and (or) during winter residency may be conducted for special wetland subpopulations of particular concern (e.g., as part of Tier 3; see Section 2.1). Auxiliary sampling at "hot spots," such as breeding colonies and concentrations of migrants, also will be an important supplement to monitoring at the Tier 2 sites. Efforts will be made to integrate on-going censuses (e.g., BBS) with the wetland-specific sampling for EMAP-Wetlands (Adamus and Brandt, 1990), particularly if only one avian census is conducted per year.

4.2.6.3 Remaining Issues

The community composition and abundance of birds are subject to considerable spatial and temporal variability. However, long-term monitoring can help identify actual trends that are obscured by annual fluctuations in species and numbers (Robbins et al. 1986). By examining the structure of response guilds (Szaro 1986, Brooks and Croonquist, in press), it is not necessary to detect all the individuals present in a given wetland, which is the likely outcome of a limited sampling effort. Using only data on species presence/absence, the functional composition of the community can be ascertained without violating the assumptions of population censuses. Field pilot studies will be conducted to determine which avian taxa and which guild combinations provide the most explanatory information about changes in the wetland resource. For example, waterfowl may be good indicators of changes in open water and emergent wetlands, whereas neotropical migrant songbirds may be more suitable for drier, forested wetlands. Finally, efforts will be made to encourage the participation of birding organizations throughout the country and also cooperative sampling with USFWS programs, as sources of both qualitative and quantitative data.

4.2.7 Community Composition and Abundance of Macroinvertebrates

4.2.7.1 Description

Aquatic insects, particularly the larval stages of groups such as dragonflies and midges, are found in all wetland types. They bioaccumulate, to some extent, and are responsive to all four major stressors (altered hydrology, excess sediment, changes in nutrient cycling, and contaminants). Benthic/epiphytic macro-crustaceans, such as amphipods, crayfish, and oligochaetes, have similar advantages as indicators. They are relatively sedentary, and thus may be indicative of chronic stressors affecting the benthos. Larger taxa, such as mollusks, are known to accumulate contaminants. Due to their immobility, they also may be good response indicators of localized pollution problems (Schindler 1987, Simon et al. 1988). Macroinvertebrates typically serve as the primary food resource for both invertebrate and vertebrate predators, and therefore can be used as an indicator of productivity as well as biodiversity.

Numerous studies have recommended that macroinvertebrates be used for biological monitoring (Hellawell 1986), because (1) identification keys are readily available; (2) diverse taxa are available to increase measurement sensitivity; (3) many species are relatively sedentary; and (4) some species are long-lived. Studies of macroinvertebrates as ecological indicators have concentrated, however, in lotic habitats, where they respond predictively to changes in water quality. Community-based metrics may be the best approach for characterizing macroinvertebrate responses to stress. Plafkin et al. (1989), following the lead of Karr (1981), developed a three-level, rapid bioassessment protocol for streams using benthic macroinvertebrates (and fish), based on previous studies and existing state sampling programs. This system has been field tested extensively and recommended for use nationally.

Unfortunately, the ecology of macroinvertebrates living in the organic substrates found in wetlands is less well known. The relationships that work for streams may not hold for wetlands. Also, the numerical and spatial variability of macroinvertebrates in wetlands appears to be much greater than that observed in streams. Detailed studies have been conducted for macroinvertebrates in emergent wetlands in conjunction with waterfowl research. Ross and Murkin (1989) provided a review of sampling techniques and suggested a protocol for long-term studies. The methods that they suggested, however, are labor intensive. Perhaps a careful study of the literature could restrict the screening of benthic organisms to a relatively few species that might be good indicators of various habitat modifications. This could lead to procedures that would be less time consuming and less expensive. Thus, the specific sampling techniques to be used for macroinvertebrates (especially benthic macroinvertebrates) in EMAP-Wetlands must be determined prior to any extensive regional field applications.

4.2.7.2 Approach

Until a standardized sampling methodology is developed for wetland macroinvertebrates, a two-phase approach is tentatively proposed. First, for wetland systems with distinct inlets, internal channels, and outlets that approximate flowing streams, the second protocol described by Plafkin et al. (1989) will be used. For riffle/run areas where flow is rapid, multiple 1-m^2 kick samples are collected and sorted. In addition, separate coarse particulate organic matter (CPOM, leaves, needles, twigs, and other plant particles > 1 mm in size) samples are taken by collecting leaves and other organic debris. The collection of a "handful" of the latter is recommended, but a more precisely defined quantity will eventually be specified (at least 100 ml).

The second phase involves sampling of wetland substrates. In saturated organic substrates, a coring device (e.g., Swanson 1978), Ekman dredge or similar device will be used to extract a sample. The core is easier to use, but samples only a very small area even if multiple samples are taken. The dredge collects a much larger sample, which reduces the variability already inherent in many wetland substrates, but it performs poorly when roots or other coarse materials are present. A simple, but repeatable technique for substrates with abundant organic matter, is to use a trough to remove a cylindrical sample 10 cm in diameter and 10 cm deep. A minimum of three samples per habitat type are required.

The material collected is then sub-sampled quantitatively in the field, taking at least three, 100-ml samples (J. Gallagher, Pennsylvania State University, pers. comm.). For samples that contain little organic matter, Plafkin et al. (1989) suggested distributing the composite sample in a gridded, light-colored pan, and collecting all organisms found in randomly selected grid cells until at least 100 organisms are collected. This technique is efficient, and also provides an index of relative abundance and biomass. Organisms may be classified in the field, although it is more likely that the sorted samples will be preserved, e.g., with a 50:50 mixture of formalin and ethyl alcohol, for later identification in the laboratory.

In wetlands having substantial areas of standing water, a collection device that samples free-swimming organisms and fauna attached to submergent and emergent plants may also be used. After testing a variety of recommended sampling devices (Murkin et al. 1983, Hepp 1987, Ross and Murkin 1989), an activity trap consisting of a collection jar and entry cone was found to collect the greatest variety of organisms without duplicating effort (Hepp 1986). The trap is set for a minimum of 24 hours, although 48 hours is preferred. An alternative technique for wetland littoral zones, that requires less time, is to make a set number of sweeps (e.g., 10) underwater with a standard "D" net. Organisms collected in these areas will be stored and analyzed separately from those collected in benthic samples.

Once the macroinvertebrates are collected, they should be identified first by functional group (shredders, scrapers, collectors, predators; Cummins and Wilzbach 1985) and order/sub-order. A gross analysis of the condition of the aquatic environment can be made at this level of taxonomic sorting. However, identification down to at least the family/sub-family level, and in some cases genus/species, is necessary to adequately assess the composition of the community relative to variable levels of water and sediment contamination, and productivity.

4.2.7.3 Remaining Issues

Metrics developed for stream surveys (Plafkin et al. 1989) may not be appropriate for the anaerobic conditions and organic matter found in most wetlands, but these metrics can serve as a starting point for future research on wetland invertebrates. The organisms collected should be properly preserved so that samples remain useful when new metrics are developed. Sampling techniques must be standardized with respect to equipment, season, wetland type, and sorting procedures, if useful comparisons are to be made among the wetlands monitored. Although macroinvertebrates are relatively easy to collect, the labor costs to sort and identify samples containing large amounts of organic material are enormous (e.g., 3-4 hours/wetland sub-sample at the Macroinvertebrate Identification Laboratory of the Pennsylvania State University, J. Gallagher, pers. comm.). The use of artificial substrates to collect colonizing organisms could be considered as a means of acquiring comparable samples over time. Terrestrial invertebrates found predominately on wetland vegetation (e.g., certain species of butterflies and grasshoppers) are not addressed in this indicator description. The variability from these samples is expected to be even greater than that of aquatic species, and thus, may not be reliably applied at this time. Pilot studies should be undertaken to determine if regional, community-based metrics for macroinvertebrates can be developed for all of the wetland types expected to be encountered.

4.2.8 Chemical Contaminants in Sediment

4.2.8.1 Description

Because of their hydrologic position on the landscape, wetlands often receive water and sediments laden with contaminants from urban and agricultural runoff, and municipal wastewater. Thus, wetlands can serve as significant "sinks" for metals and organic compounds through sediment accretion. The public has become increasingly concerned about the effects of these accumulated contaminants on public health and ecological resources. Measurement of contaminants in the water column is subject to significant temporal and spatial variation, particularly after extreme rainfall events. Given the infrequent sampling protocol required for EMAP, sampling for contaminants in sediments should provide more consistent results than samples taken from the water column. As an indicator of exposure, the levels of contaminants in sediments would be expected to have both direct and indirect negative effects on all three wetland assessment endpoints of concern: productivity, biodiversity, and sustainability. In addition, the outputs from these analyses could be integrated into ongoing efforts at EPA to define sediment quality criteria.

4.2.8.2 Approach

Mid-growing season is an optimal period for sampling chemical contaminants in wetlands, when metabolic and assimilation rates of biota are at their peak and background ambient concentrations are expected to be minimal and relatively constant. Multiple samples will be collected in conjunction with other routine sampling efforts (e.g., measures of sediment fluxes), but samples may be composited to reduce analytical costs. Initially, sediment cores will be collected at variable depths from areas within the wetland that were stratified for other indicators. Soil column profiles could be measured to provide a historic record of deposition and accumulation. Samples could be measured, for example, from the surface to a depth of about 50 cm at 10-cm intervals; 5-cm intervals may be appropriate in areas of low sediment accretion. Sampling efforts in subsequent years would then concentrate in newly deposited layers, as determined from the measures of sediment accretion described in Section 4.2.4. Assessments of contaminants in sediment profiles would be repeated at less frequent intervals (i.e., > 4 years).

A variety of coring devices are available, including some that isolate the sample from atmospheric conditions to preserve the integrity of chemical constituents and the microbial community. A corer with a diameter of either 2.5 or 5 cm is commonly used and allows collection of a manageable field sample.

Sediment samples will be screened for some of the most common metal and organic pollutants. Those compounds testing "positive" may be analyzed in greater detail (quantitatively and for related compounds). Selection of the initial array of compounds for screening will reflect the expected kinds of contaminants emanating from the surrounding watershed and also possible routes of transport into the wetland (via air, water or sediment; direct discharge). Heavy metals (Pb, Cd, Zn, Ni, Cu) may be found in urban runoff and industrial wastewaters; Fe, Mn, Al, and sulfates are of concern in coal-mining regions; and pesticides and toxic salts may be found in agricultural runoff. EPA regional staff are expected to provide input into the selection of which contaminants to monitor.

The initial choice of a depth interval for sampling contaminants in the soil column may be refined by establishing a reduction-oxidation (redox) profile for selected areas within the wetland. Reliable field techniques and equipment are available to determine where in the soil profile oxygen becomes limiting (Faulkner et al. 1989; L. Lee, pers. comm.). The interface between aerobic and anaerobic zones is a likely place for some contaminants (e.g., metals) to concentrate, as they are transformed from one valence state to another. Redox measurements also provide corroborative data for other indicators, such as hydrology (e.g., depth to saturated zones).

4.2.8.3 Remaining Issues

The direct measurement of contaminants provides valuable background data for interpreting the results from other indicators and assessing possible causes of subnominal wetland condition. In particular, data on chemical contaminants in soils may be directly linked to the bioaccumulation of contaminants in wetland biota (Section 4.2.9) and indirectly to changes in biotic community composition. Although information on chemical contaminants is essential, the analytical costs can be quite substantial. Thus, decisions must be made regarding the number of samples and spectrum of contaminants to be examined. Most likely, sites will be characterized by an initial sample, with subsequent samples taken after one or more EMAP cycles. Alternatively, more intensive sampling may be conducted at a statistical subset of the Tier 2 sites, to characterize contaminants in the regional wetland population. Input from EPA staff from each region will be sought as a means to screen potential contaminants for measurement. The contaminants monitored for EMAP-Wetlands will be generally consistent with those measured by other EMAP resource groups.

4.2.9 Bioaccumulation in Tissues

4.2.9.1 Description

The discovery of massive die-offs or the absence of a species from a community can suggest that lethal exposure levels of a contaminant have occurred. Bioaccumulation monitoring, however, can identify sub-lethal and chronic, low-level exposure to a source of pollution. Bioaccumulation of contaminants in aquatic organisms has been investigated extensively (e.g., Cairns and Dickson 1980, Biddinger and Gloss 1984, Hellawell 1986, USFWS and USGS data bases).

Detection of intermittent pollution sources is strongly dependent on the time and place of sampling (Root 1990). Therefore, measuring bioaccumulation can be more informative than water or sediment testing alone, because the amount of exposure received by an organism over time is reflected in the level of contaminants found in its tissues. The methods for analysis of tissue samples are well developed; however, the choice of an organism and the specific tissues to be monitored is highly dependent on the kinds of pollution expected for a given area. Bioaccumulation offers the advantage of a chemical-by-chemical approach for determining the health of the Nation's wetlands (Brown et al. unpublished). Increases in contaminant bioaccumulation may affect wetland productivity, biodiversity, and sustainability.

4.2.9.2 Approach

All multi-celled organisms are potential candidates for bioaccumulation sampling. The types of organisms to be used for EMAP-Wetlands will be (1) common in all or most wetland classes and regions, (2) relatively immobile (at least during a designated stage of their life cycle), (3) occupy a high trophic level, and (4) be able to bioaccumulate a variety of contaminants. Longer-lived organisms integrate exposure levels over longer periods of time, so selection of a species or age class can greatly influence results. Aquatic macrophytes, macroinvertebrates, amphibians, bird eggs or young, and small mammals may be preferable for detecting short-term exposures, whereas woody plants, fish, turtles, large adult birds, and furbearing mammals may be better for monitoring long-term exposures. How a contaminant is transported and acquired by an organism will influence the selection of appropriate species.

Variability in tissue residues can be potentially high within the same sampling unit. Many factors can affect tissue concentrations, including species, age, tissue type, diet, season, and the length of exposure. Therefore, a sufficient number of individuals from each sampling location will be collected to overcome the limitation imposed by within-wetland variability.

4.2.9.3 Remaining Issues

The advantages of assessing bioaccumulation as an indicator of exposure become disadvantages in terms of costs. Levels of contaminants in plant and animal tissues may be the most costly of indicators to monitor, because of the vast array of contaminants present in the environment. As a result, it may be desirable to limit bioaccumulation measurements to only a subset of the EMAP-Wetlands sites, focusing on those wetland classes where high levels of contamination are expected. Synoptic sampling of contaminants in sediments can serve to screen sites for bioaccumulation studies. If cost-effective micro-analytical techniques become available, the proportion of sites sampled can be increased. Further work, coordinated with other EPA programs and other federal agencies, is also needed to identify the most appropriate target organisms and tissues for analyses of bioaccumulation in wetlands.

4.2.10 Nutrients in Sediment and Tissues

4.2.10.1 Description

High nutrient loadings from urban and agricultural runoff and wastewater inflows are primary stressors of wetland systems and important factors influencing wetland productivity and sustainability. Yet, measurements of nutrient dynamics have seldom been made systematically across regions or for many wetland types. Monitoring of water quality has focused on large rivers, lakes, and reservoirs rather than wetlands, although this may have led unintentionally to an assessment of nutrients in the fringing wetlands along these waterbodies. Most of the data on wetlands, per se, comes from monitoring studies of wetlands receiving municipal wastewater, with the majority being found in southern states, particularly Florida (Adamus and Brandt 1990). Publications by Nixon and Lee (1985) and Hammer (1989) summarize much of this information.

In general, freshwater wetlands are characterized as absorbers of nitrogen (N) and phosphorus (P) during the growing season, and releasers of N and P after senescence, typically in late summer and fall. Mass balance studies, however, indicate that wetlands are nutrient sinks overall. The average uptake of freshwater wetlands in the southeastern U.S. was 45% for incoming N and 56% for P; data for other regions of the nation were considered too variable to establish general trends (Nixon and Lee 1985).

4.2.10.2 Approach

A number of alternative approaches are still being considered for assessing nutrient levels in wetlands in EMAP; the procedures described below are tentative. In particular, an overall strategy for nutrient sampling may be appropriate, applying greater sampling effort in those wetlands where nutrients are most likely to cause significant impacts based, for example, on a geomorphological classification scheme of basin, riverine, and fringe positioning in the landscape (Brinson 1988).

Samples of benthic sediments and (or) vegetative tissues will be collected for nutrient analysis during routine sampling for other indicators. In addition, as auxiliary information, the water column, when present, will be sampled according to the protocols established for other surface waters (e.g., in EMAP-Surface Waters and EMAP-Near Coastal). For wetlands without open water, water samples may be taken from adjacent waterbodies. Inlets and outlets will also be sampled, whenever they can be clearly identified. If coupled with flow measurements and climatic information, these values may show less unexplained variability than would random sampling within the wetland. Benthic sediments can be collected using the same coring devices described for chemical contaminants (Section 4.2.8). Plant samples will be from mature leaves prior to senescence; analyses and data interpretation would need to be species-specific. Samples will also be collected at obvious pollution discharge points.

Water, sediment, and plant tissue samples will be analyzed for total Kjeldahl N (TKN), total phosphorus (TP), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), sulfate (SO_4), chloride (Cl), conductivity, acid neutralizing capacity, and pH. In situations where additional information on N and P species warrants the additional costs for analysis, levels of NO_x, NH_4, organic N, PO_4, and organic P may also be determined.

4.2.10.3 Remaining Issues

Nutrient concentrations in wetlands tend to be highly variable, both spatially and temporally. Large fluctuations are likely to occur following major climatic events and anthropogenic disturbances. Thus, samples collected following these events may diverge dramatically from expected results. Nutrient concentrations are directly affected by water volume and movement, so their measurement should be integrated with hydrologic sampling. Nutrients affect and are affected by vegetation, particularly herbaceous plants, so integration with the monitoring protocols for plant communities is also essential. Sediment nutrients will be affected by both inputs and the composition of parent materials.

The challenge for EMAP-Wetlands is to develop a suitable indicator(s) of nutrient flux than can be measured infrequently (e.g., once every four years during the proposed index period) and still yield meaningful results for regional assessments of the condition of wetland resources. Most sampling protocols developed to date require intensive sampling, and may have poor diagnostic utility if samples are collected less frequently or with less comprehensive spatial coverage. Further analyses of existing data bases as well as field pilot studies are needed to determine whether and how best to sample nutrients for EMAP-Wetlands. Because nutrient dynamics are less well known in wetlands, than in surface waters, the measurement of nutrient concentrations is considered a low priority research indicator for EMAP-Wetlands at this time.

4.2.11 Observational Data

In addition to the aforementioned indicators, EMAP-Wetlands will also record observational field data which requires no laboratory analyses. For example, high water marks, debris accumulations, ice damage, canopy die back, and the presence of unusual amounts of fallen limbs, damaged and uprooted trees, etc. are inexpensive and potentially useful and repeatable indicators in forested wetlands. Proposed observational indicators of herbaceous wetlands will be developed. Field forms will be developed to standardize methods for evaluating and recording these data.

4.3 FUTURE RESEARCH

This subsection highlights the priority future indicator research activities necessary to advance the proposed wetlands indicators through each phase of the indicator development process outlined in Figure 4-1. An overview is provided of the priority existing data sets to be analyzed; and field pilot studies and regional demonstration projects are discussed.

4.3.1 Analysis of Existing Data Sets

Synthesis and evaluation of existing data provide a cost effective means to assess EMAP-Wetlands objectives prior to field studies. The objectives of analyzing existing indicator data bases are as follows:

- Evaluate and quantify spatial and temporal variability.
- Assess various metrics' sensitivity to controlled or induced stress, or altered forcing functions.
- Identify new candidate indicators of wetland condition.
- Initiate development of community metrics using vegetation, macroinvertebrate, and bird data.

Existing data sets considered useful for analysis have one or more of the following characteristics:

- studies of research indicators conducted for durations > five years,
- studies of multiple responses of indicators to induced wetland stress, or
- regional data sets of wetland condition or paleoecology.

Data from pertinent regional and (or) long-term wetland data sets which meet these criteria will be catalogued for later use for defining expected normal ranges of indicator values for wetland classes in each region (see Section 2.2). To assure appropriate interpretation and application of existing data, it will be important to convene working groups, of both EMAP-Wetlands staff and regional wetland indicator experts. Before assessing and analyzing appropriate data sets, working groups will meet with the project principal investigators and evaluate whether:

- o the indicator data are expected to respond to wetland stressors (hydrologic and physical alteration, eutrophication, contamination); and
- o the variability of monitored indicators will be manageable when incorporated in the EMAP framework.

If the answer to both of these questions is affirmative, then the data sets will be deemed appropriate for analysis in EMAP-Wetlands. Data sets being considered for analysis at this time are listed in Table 4-4.

Proposed indicator specific data sets to be analyzed include the following in priority order:

1. hydrology,
2. landscape and wetland pattern,
3. vegetation,
4. sediment characteristics,
5. bird communities,
6. chemical contamination and bioaccumulation,
7. nutrient concentrations,
8. macroinvertebrates, and
9. amphibians.

Hydrology, as the major driving force on wetland function, is an essential indicator for both analysis of existing data and proposed field studies. The frequency and accuracy of hydrologic measurements required to interpret changes in other indicators must be defined. The most appropriate and sensitive attributes for detecting wetland stress need to be identified. Additional data sets (not included in Table 4-4) to be analyzed for hydrologic parameters include

- o USGS's WATSTORE -- to evaluate the sensitivity of hydrologic metrics; and
- o SCS's Soils 5 data -- to help approximate the hydrologic frequency, duration, and season of flooding in wetlands where data are present.

For landscape and wetland pattern, the major challenge ahead is to identify which landscape pattern metrics are the most sensitive to landscape stress and are of greatest consequence to wetland function and condition. This evaluation could be conducted using either existing data or photographs for a planned field study. Once the information is put into a GIS, analysis of proposed landscape metrics would proceed very quickly. EMAP-Wetlands proposes to evaluate the sensitivity of landscape pattern metrics using one or more of the following photo-sources:

Table 4-4. Examples of Some Long Term Wetland Research Sites.

SITE	DATES OF DATA	ATTRIBUTES MONITORED	COMMENTS
1) Cedar Creek LTER site, MN	Info since 1940s LTER since 1982	-Variation in wetland/upland boundary -Nutrient budget and cycles -1° production and disturbance patterns	Marsh & Shrub swamp Conifer bog
2) Illinois & Missouri Rivers LTER site, Il	Info since 1940s LTER since 1982	-Controls of productivity -Material transport -Relationship between community structure, geomorphic structure, and hydrologic regime Annual birds	Aquatic beds Freshwater marsh, forests 6+ years plants
3) Jordana Desert LTER site, NM	Info since 1915 LTER since 1981	-Factors affecting primary production -Nitrogen cycling -Organic matter transport and processing -Vertebrate and invertebrate population	Desert playa 9 yrs. nitrogen & phosphorus
4) Niwok Ridge/Green Lakes Valley LTER site, CO	Info since 1951 LTER since 1981	-Plant community, disturbance, and recovery -Climatic change and vegetative communities -Decomposition and nutrient cycling	Wet tundra Alpine marsh
5) North Inlet Estuary LTER site, SC Baruch Estate	Info since 1970 LTER since 1981	-Transport and fate of materials and nutrients from uplands -Patterns and controls of organic matter accumulation	Cypress swamp, 15+ yrs water budget and hydroperiod information
6) Pymatuning Laboratory of Ecology, PA	-	-Nutrients -Algal and vascular plant communities -Macroinvertebrates -Small mammal communities	
7) Northern Prairie Wildlife Research Center, ND	-	-Vegetation -Macroinvertebrates related to waterfowl food -Water levels	
8) Okefenokee National Wildlife Refuge LTER, GA	-	-Algae, vascular plants -Hydrology, water quality	Freshwater marsh, forested wetlands
9) Kellogg Biological Station, MI	-	-Hydrology, water quality -Vegetation -Agricultural impacts	Streams

Table 4-4. Examples of Some Long Term Wetland Research Sites (cont.)

SITE	DATES OF DATA	ATTRIBUTES MONITORED	COMMENTS
10) Houghton Lake, Drummond, Bellate wastewater sites, MI	Since 1970s	-Hydrology, water quality -Vegetation	Peatland, marsh, fen
11) White Tail Farms, NC	Since 1980s	-Hydrology, water quality -Vegetation	Peatland
12) Delta Waterfowl and Wetlands Res. Sta. Canada	1979 -1989	-Vegetation -Macroinvertebrates -Birds -Hydrology -Decomposition -Succession	Northern prairie marshes Control and managed prairie potholes 11 yrs of N/P birds/plants hydroperiod/ macroinvertebrates
13) U.S. Army Corps of Engineer Waterway Expt. Sta., MS			Dredged material program GIS database of 1000 plots in lower Mississippi floodplain
14) Consulting Ecologists, Inc. (Kevin Erwin), FL	3-5 years	-Hydrologic parameters -Vegetation -Macroinvertebrates -Wildlife	Newly created mitigation sites, reference sites Forest & marsh wetlands
15) Everglades National Park, FL	20+ years	-Hydrology -Vegetation	
16) University of Wash. (Richard Horner), WA	5 years	-Vegetation -Hydrology -Sediment -Water quality -Macroinvertebrates -Wildlife, etc.	20 reference & sewage influenced emergent and forested wetlands

Table 4-4. Examples of Some Long Term Wetland Research Sites (cont.).

SITE	DATES OF DATA	ATTRIBUTES MONITORED	COMMENTS
17) Pennsylvania State Univ. (Robert Brooks), PA	3 years	-Vertebrates -Vegetation -Hydroperiod -Water quality -Macroinvertebrates	65 freshwater wetlands 24 sites in GIS
18) Smithsonian Environmental Research Center (Chesapeake Bay)	Since 1971	-Vegetation -Hydrology, water quality	Tidal and forested wetlands
19) Atchafalaya & Barataia Basin, LA			
20) North Temperate Lakes LTER site, WI Trout Lake System	Info since 1940s LTER since 1982	-Groundwater hydrology & geochemistry -Paleolimnology -Producer and consumer ecology	Sphagnum leatherleaf Conifer swamps 6 yr. herb plants data 6 yr. acidity data
21) Baratia Basin Bottomland Hardwood, LA	Info since 1978	-Response of vegetation to flooding -Stress and elevational changes	12+ years vegetation, growth, decomposition data
22) Boeuf Lake Floating Marsh, LA	Info since 1981	-Patterns and control of primary production in floating marsh	Floating-emergent marsh 9 year herbaceous plants + 1° productivity data
23) Corkscrew Swamp Sanctuary, FL	Info since 1974	-Succession and production of wetland -Influence of hydrologic variables and disturbance	Pine wetland Hardwood hummocks Mineral & organic soil marshes
24) Savannah River Ecology Lab., SC	Info since 1952	-Ecosystem effects of thermal stress and pollution -Effects of radioactive contamination -Recovery of wetlands from severe disturbance (thermal stress, flooding, sedimentation) -Secondary succession	Cypress swamp 2 years N/P/heavy metals 16+ years vegetation Passerline info sincel 1955
25) Virginia Coast Reserve LTER site, VA	-	-Salt marsh ecology and hydrology -Primary and secondary succession	Salt marsh estuary

Table 4-4. Examples of Some Long Term Wetland Research Sites (cont.).

SITE	DATES OF DATA	ATTRIBUTES MONITORED	COMMENTS
26) Harvard forest LTER site, MA	-	-Climatic changes and disturbance history and vegetation dynamics -Comparison of community population and vegetation response to human and natural disturbance -organic matter accretion	Spruce swamp forest
27) H.J. Andrews Experimental Forest	-	-Hydrology, water quality, vegetation	
28) Cache River, IL	-	-Invertebrates, fish, vegetation, hydrology, water quality	
29) IMPAC Program, FL	Since 1974	-Vegetation, water, quality, hydrology	Pine flatwoods

- NWI digitized data for the EMAP 40 km^2 hexagons,
- SCS county office photo sets for farmland and surrounding areas, and
- EPA, State Departments of Transportation, or USGS photos.

Sediment Characteristics are useful as indirect measures of hydrology and cumulative stress on wetlands. Large data sets are available on organic matter, bulk density, and C/N ratios, and will be used to quantify indicator variability and select appropriate samples sizes at Tier 2.

For vegetation, the following data sets and analyses are being considered:

- state and regional range distribution maps for flora, as one source of information on historical botanical reference conditions;
- analyses of large data sets on wetland plant communities to evaluate the Weighted Average indicator (see Section 4.2.4) and successional trends in wetlands (Table 4-4).
- vegetation biomass and species composition data sets, to be used to anticipate the necessary sample sizes for monitoring each class in each region, where data are available.

Bird community data show promise as a means of monitoring regional changes in wetlands. A subset of existing BBS routes that occur primarily in wetlands could be examined across a region that has a gradient from reference to disturbed sites. Breeding Bird Atlas (BBA) data may also be available for some of the EMAP 40-hexes. The species lists that are generated might be used to test or develop community-based metrics, such as guild rankings, that reflect different levels of impact. The sensitivity and variability of the community based metrics could be examined using BBS, BBA, and CBC data.

Chemical contamination and bioaccumulation have not been adequately documented for wetlands. Thus it will be important to

- identify priority contaminants and deemed locations, as predicted by regional experts (including Regional EPA offices);
- work with the EPA at Cincinnati, USFWS, and USGS, to select the appropriate organisms to be sampled as bioaccumulation indicators;
- work with the EPA at Cincinnati, USFWS, and USGS, to select appropriate tissues to be sampled for bioaccumulation analyses; and
- determine the spatial variability in wetland contaminants in soils and determine which toxins are to be analyzed.

The USFWS Contaminants data base will be analyzed and interpreted in the context of the laboratory toxicity data compiled in

- Phytotox and UTAB-Dept of Botany, University of Oklahoma (data on growth and development of terrestrial plants and threatened and endangered plant species exposed to organic chemicals in sewage sludge) and
- AQUIRE (Aquatic Information Retrieval), a very large data base of national and international scientific literature (1972 to the present) established in 1981 by EPA. AQUIRE contains an integrated evaluation of toxicity test results of individual chemicals on aquatic organisms and plants. Acute, sublethal, and bioaccumulation effects are included for tests of freshwater and marine organisms.

Given the highly variable nature of nutrient concentrations in wetlands, we must determine if/how to interpret data collected at the proposed sampling frequency of only once every four years. Experts need to further examine the range of values in the literature and unpublished studies. Appropriate sources of long-term data to be analyzed are located in

- o Donald Hammer's book, Constructed Wetlands, which includes information on nutrient concentrations in many different wetland types;

- o Robert Kadlec's long-term data sets on nutrient concentrations in wetlands;

- o USGS's WATSTORE data base, which would allow for retrospective analyses of water quality parameters in streams that feed to or from wetlands;

Macroinvertebrates, deemed a predictive indicator capable of recording wetland responses to all types of stress, deserve high priority in research efforts. To date, however, regional macroinvertebrate data sets and corresponding tolerances to stress have not been compiled. Compilation of these data sets will be a high priority for EMAP-Wetlands. The initial emphasis for analyses of compiled data will be on developing and evaluating community-based metrics similar to those for streams (Plafkin et al. 1989). The proposed macroinvertebrate community index would need to be adapted regionally to account for community parameters and stressors found in wetlands. Help from EPA's Wetlands Research Program is anticipated. Indicator data sets to be analyzed include the following:

- o G. Swanson's extensive multi-wetland data set of macroinvertebrates in North Dakota (Northern Prairie Wildlife Research Center) and

- o EPA's BIOS data set including regionally extensive data on macroinvertebrates in relation to water quality (aquatic macroinvertebrates).

Amphibians are deemed a predictive indicator of aquatic habitat stress. Existing data sets for amphibians will be examined for evidence that certain species or taxa may be suitable indicators of wetland condition. Investigations of the literature and data bases on bioaccumulation of long-lived herpetofauna will be undertaken. Justin Condgon and J. Whitfield Gibbons at the Savannah River Ecology Laboratory have a long term (10-15 years) data set on amphibians and reptiles.

Indicators were considered of lower priority for EMAP-Wetlands if either existing data sets were lacking for indicator evaluation or considerable methods development was required prior to field testing. The analysis, testing, and evaluation of these low priority/low confidence research indicators may be conducted in coordination with EPA's Wetland Research Program in Corvallis, OR. The Wetlands Research Program (WRP) is interested in advancing indicator research so as to better define, evaluate, and predict wetland mitigation success, to evaluate the functioning potential of a wetland within a landscape, and to evaluate proposed water quality standards for wetlands at the state level. Specifically, site-specific indicators are of interest to the Mitigation and Constructed Wetlands component of the Wetlands Research Program. The Cumulative Impacts program component is interested in landscape level indicators, including greenness. The WRP may initiate mesocosm cause/effect experiments to (1) verify the correlation of subnominal wetlands with proposed stressors and to (2) develop diagnostic indicators for subnominal wetlands. Proposed activities for further development of the lower priority research indicators in EMAP-Wetlands are discussed in the following paragraphs.

Mammal populations in wetlands often act as biotic forcing functions, altering the vegetation composition or hydrologic regime. Existing data sets for mammalian communities will be examined for evidence that certain species or taxa may be suitable indicators of wetland condition. Regional experts will be contacted for empirical evidence that support the use of mammals as wetland indicators. Investigations of the literature on bioaccumulation in mammals will also be undertaken. To date, EMAP-Wetlands is not certain how to incorporate presence/absence of mammal community measurements. Data sets to be analyzed include the following:

- o Robert Brooks, Pennsylvania State University, has small mammal data from 65 wetlands of variable types in Pennsylvania.

- o Maurice Alexander, Syracuse University, has a long term data set which documents both furbearer and marsh vegetation dynamics.

- o The Louisiana Deptartment of Wildlife and Fisheries (Greg Linscombe) and New York Department of Environmental Conservation (Mark Brown and Gary Parsons) have documented population dynamics of beaver, muskrat, nutria, otters, and raccoons. In addition, tissue samples were collected cooperatively for testing contaminant concentrations.

Greenness, a remotely sensed indicator of vegetation robustness and vigor, has great potential as an EMAP-Wetlands response indicator. However, data interpretation procedures are not fully developed. Data may be analyzed from a landscape perspective, if high resolution data from SPOT or LANDSAT are used.

A working group will be established to evaluate microbial community data and its utility to EMAP-Wetlands. Microbial communities are generally sensitive to inputs that alter environmental conditions, such as flooding, nutrient-laden runoff, and toxics. Microbes also have long been used as indicators of pollution (Kolkwitz and Marsson 1908). Organic enrichment causes excessive growth of bacteria in streams. Toxic chemicals affect microbial assemblages in much the same way as they affect larger taxa; species richness declines, community composition changes, and biomass shifts (J. Pratt, pers. comm.). Methods have been developed to characterize eukaryotic microbial communities and cyanobacteria. However, numerous questions requiring additional research remain. Can technicians be trained sufficiently and cost-effectively in microbial taxonomy? What is the best means of collecting samples (in conjunction with other indicators versus artificial substrates)? Can sampling of microbial populations conform to the sampling regime of EMAP? Additional research is needed before microbial community composition can be implemented as an EMAP-Wetlands indicator.

Compiling and analyzing the aforementioned data sets will be a large challenge. Another challenge facing EMAP is to develop a logical cost-effective strategy for incorporating historical data, including old aerial photographs, tree ring data, and paleoecology data sets into indicator analysis and interpretation. Historical information could be used to quantify the long-term natural temporal variability, needed for interpretation of EMAP-Wetlands trend results. Tree ring data and aerial photographs would explain historical natural and anthropogenic stressors on scales of decades to centuries, while paleoecological data sets could provide historical interpretation for up to millennia. Another use of paleoecology and aerial photography is to determine which wetland types (size, shape, and class) are most stable over time, and thus identify potential time frames for natural wetland succession. Paleoecology data could also be used to interpret contaminant data by correlating plant community data (pollen and bryophytes) with (1) the initial appearance of contaminants in the environment or (2) sedimentation rates and known landscape changes. Paleoecology techniques are most useful when applied selectively to wetlands which normally experience stable system inputs, such as bogs and old growth forests, rather than "ephemeral" systems, such as alluvial floodplains and marshes.

4.3.2 Pilot Studies

The general objectives for field pilot studies are listed in Section 2.6.2. Field tests will be conducted to assess the variability and sensitivity of the proposed EMAP indicators that are considered of highest priority (See Table 4-2) or with particular potential for further development These indicators have previously been used to describe and evaluate individual wetland sites. EMAP-Wetlands proposes, therefore, to field test the following indicators in 1991:

- o landscape indicators,

- o indicators of hydrology, as quantified in a simple manner,

- o sediment characteristics,
- o vegetation community composition and abundance,
- o macroinvertebrate composition and abundance,
- o contaminant concentrations in sediments, and
- o nutrient concentrations in sediment and/or tissues.

These indicators will be field tested in two or more regions for each wetland class prior to advancing their application to the regional demonstration project phase. Ultimately, these proposed indicators will be field tested in all wetland types and regions.

Amphibians, mammals, bioaccumulation, and microbial community composition indicators will be field tested in later years, after the available baseline data have been compiled and evaluated for each wetland class in each region and the indicators are deemed ready for field testing by working groups. Field testing of these indicators may be conducted in cooperation with the EPA Wetlands Research Program.

4.3.3 Regional Demonstration Projects

EMAP-Wetlands indicators data will be applied in regional demonstration projects only after the completion of successful testing and evaluation during pilot projects. Regional demonstration projects will allow the evaluation of indicator specificity, sensitivity, reliability, and repeatability over a broad range of environmental conditions (see Section 2.6). In addition to evaluating indicators previously tested in pilot studies (see above), indicators of wetland extent and landscape pattern will be applied and evaluated in the regional demonstration projects. Minor details for applying wetland extent and landscape pattern to EMAP's hexagon format need to be worked out.

In summary, the high priority EMAP-Wetland indicator research needs are as follows:

- o Analyze existing indicator data.
- o Determine a strategy for the use of historical or retrospective indicator data.
- o Apply the high priority, high confidence wetland indicators in pilot projects.
- o Develop analytical tools for analysis and interpretation of vegetation data, bird data, macroinvertebrate data, sediment accretion rates, and hydrology.

5.0 FIELD SAMPLING DESIGN

This section describes the proposed approach for gathering field information and obtaining biological, physical, and chemical samples from wetlands selected for field visits in Tier 2 of EMAP-wetlands. Section 5 presents an overview of when, where, and how the field measurements will be collected. More specific discussions for each proposed EMAP-Wetlands indicator were provided in Section 4.2. Efforts to date have focused on defining when field samples will be collected. The where and how components of the field sampling procedures have not yet been addressed. The specific sampling design will vary for different wetland classes and will be described in field training and operational manuals to be prepared prior to each phase of field activities (pilot studies, regional demonstration projects, and national implementation).

5.1 INDEX CONCEPT

Biological, chemical, and physical characteristics of wetlands vary both temporally and spatially. In order to minimize the sampling variability that results from this inherent natural variability, broad scale surveys and trend monitoring networks have used both temporal and spatial indices to characterize sample units. If properly designed, the index values obtained from such studies can be used to classify individual study sites, detect trends through time, and provide the basis for regional-scale analyses of resource condition and trends. The optimal field sampling design depends on the project objectives as well as the variability of the indicators to be measured. Both temporal and spatial aspects of index measurements must be considered.

5.2 INDEX PERIOD

The ideal sampling period is when (1) the indicator biota are present, (2) the data collected provide an integrated measure of wetland condition throughout the year, and (3) the response and exposure indicators exhibit low temporal variability at the sampling site. In addition, to facilitate diagnosis of probable causes of subnominal wetland condition, the index period should coincide with the period of maximum environmental stress on the indicator biota and wetland ecosystem. The optimal sampling time may vary for different indicators. The index period selected, therefore, must be appropriate for most indicators and optimal for the group of indicators, as a whole.

The proposed index period for sampling wetlands is mid-growing season, generally in July and August for most areas of the country. Specific sampling times in each region will be adjusted to account for latitudinal and elevational gradients. During this period, most biological indicators, and in particular wetland vegetation and soil characteristics (e.g., soil organic matter, accretion rates, and contaminant concentrations), are present and representative of the year's hydrologic, chemical, and physical regimes. Thus, even though mid-growing season may not be the time of maximum hydrologic stress, these integrative indicators of wetland condition reflect the hydrologic conditions and stressors experienced throughout the year.

All wetland indicators will be monitored during this proposed index period, as an index of regional wetland condition. However, several indicators (e.g., hydrology) may also be measured at additional times of the year in a statistical subset of the EMAP-Wetlands Tier 2 sites. As noted in Section 4, indicators that will not be well characterized by sampling only during the proposed index period include wetland hydrology, migrating fauna (e.g., waterfowl), and amphibians. Special field sampling efforts to monitor these indicators are being considered, and will be evaluated as part of field pilot and demonstration projects.

5.3 SAMPLING LOCATIONS

The field sampling design must also account for spatial variations in indicators within a given wetland. Because of the large spatial variability in most wetlands, indicator measurements and samples will generally be collected at multiple locations. The optimal spatial sampling design has not yet been determined, however. Additional analyses are planned to evaluate the relative merits of grid designs, cluster sampling designs, and sampling transects for EMAP-Wetlands. The optimal design and sampling locations will differ for different indicators. Thus, the final design selected will be a compromise, addressing the spatial requirements of the majority of indicators.

At present, the field sampling design proposed for discrete wetlands is to use three transects running parallel to the hydrologic gradient (i.e., perpendicular to major changes in the vegetation community). Transects have traditionally been used to sample wetland sites because of the strong environmental gradients (in hydrology, vegetation, substrate, and fauna) that occur in most wetlands. Issues that still need to be resolved, however, include:

- Optimal (maximum) transect length;
- Number of plots necessary per transect to adequately characterize the site, given that the data are to be used to assess regional, not site-specific, wetland status; and
- Procedures for selecting transect locations and the placement of indicator plots along the transects.

The field sampling design proposed for sampling extensive homogenous wetland resources is the randomly placed clustered quadrant approach, with clusters of sample plots radiating out at fixed distances from a center point (Figure 5-1). This sampling strategy has been used successfully by both the U.S. Forest Service and EMAP-Forests. However, for wetlands, the sampling design will be modified so that one resulting transect or spoke will be oriented along the axis of the major hydrologic gradient in the wetland. Additional issues that need to be addressed include the following:

- How would the center points of the clusters be selected?
- What is the appropriate number of clusters and number of rings per cluster needed to optimize data collection efforts aimed at one day per site?
- In how many plots, and in which plots, would each indicator sample be collected?
- Would all ecotypes be sampled in the wetland? Should one community type be sampled to represent the entire wetland?
- Is this sampling strategy preferable over straight transect sampling?

5.4 FUTURE RESEARCH

Analyses of existing data sets, field pilot studies, and regional demonstration projects will be used to finalize and evaluate the EMAP-Wetlands field sampling design. The results from these studies will be used to select the optimal field sampling design for characterizing regional wetland health, balancing the need for more information per site versus the need for data on more sites per region. Design components that need to be resolved prior to implementation include the following:

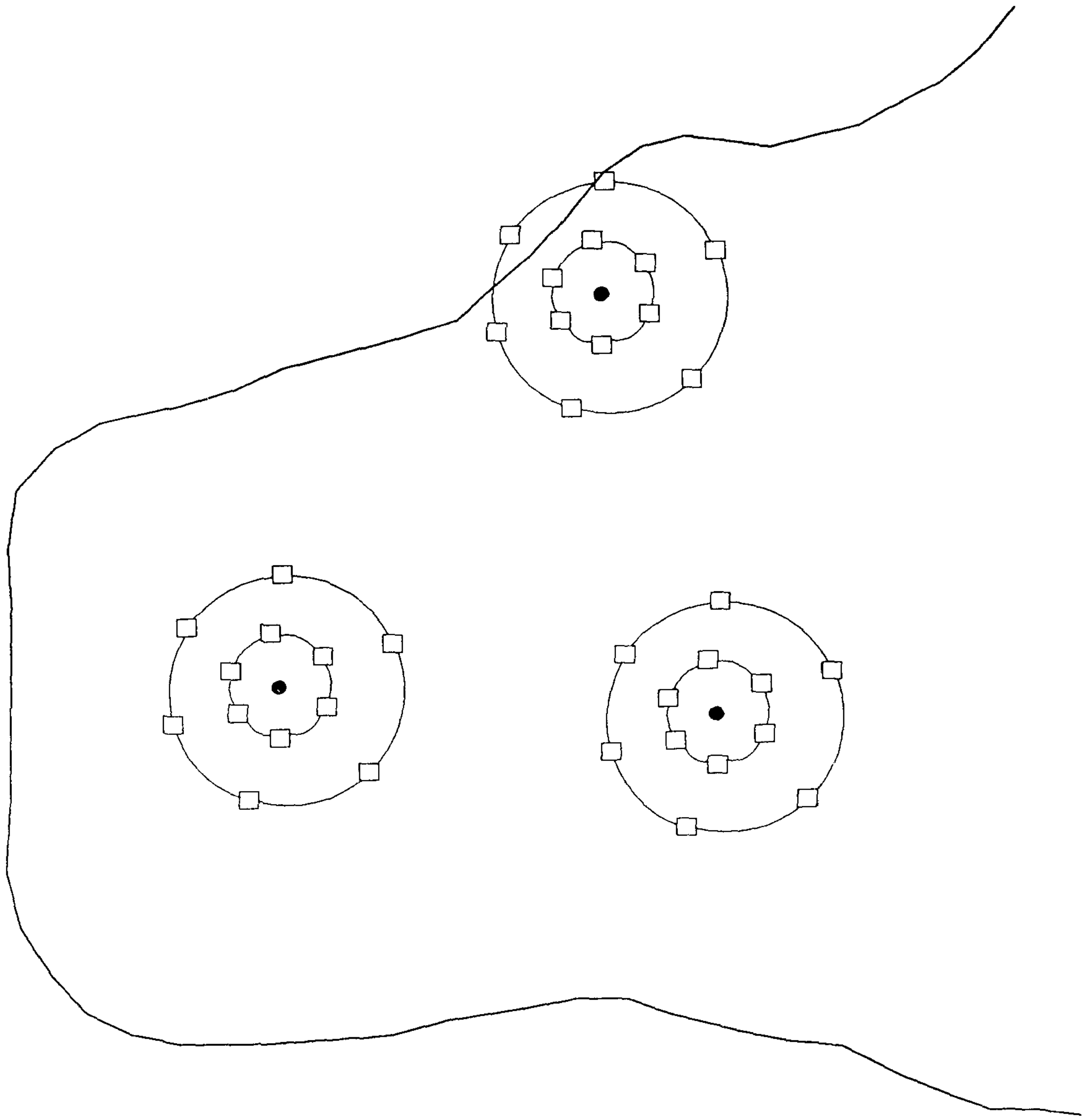

Figure 5-1. Proposed conceptual field sampling design for extensive wetland resources.

- o Appropriate sampling designs -- Is a transect, cluster, or grid design best suited for capturing intra-site variability?

- o Density and frequency of sampling necessary to characterize the proposed indicators at a site -- How many plots along a transect are necessary to represent the wetland site? How many transects are needed?

- o Sampling methodologies -- What are the most appropriate survey sampling methods for the proposed indicators?

- o Index period -- Does the proposed index period result in the lowest possible intra-site variability?

National implementation of EMAP-Wetlands will ultimately involve monitoring multiple wetland classes in all regions of the country. The proposed index period and sampling design strategy must be flexible to account for variations in wetland characteristics and responses among regions and among wetland classes. Sampling periods will need to be researched and adapted for each wetland class in each region. In addition, basic differences among wetland classes may require adaptations of the spatial sampling design.

6.0 DATA ANALYSIS

This chapter outlines the types of data analyses to be conducted using the EMAP-Wetlands monitoring data to achieve the program objectives defined in Section 1.2. Development of data analysis procedures will be an ongoing activity of the program. The following, therefore, provides only a general overview of the types of analyses planned and outputs expected. It is likely that these ideas will be refined and expanded as program planning and evaluation proceeds, by analyzing existing data sets, conducting "mock" or example interpretive assessments with simulated data sets, and during analysis of the data collected in the pilot and regional demonstration studies. Prior to program implementation, an EMAP-Wetlands Data Analysis Plan will be prepared including specific data analysis algorithms. The development of methods for data analysis is a joint effort of EMAP-Wetlands, the EMAP Design task group (see Overton et al. 1990), EMAP Integration and Assessment task group, and the other EMAP resource groups.

The data analyses to be conducted for EMAP-Wetlands fall within six major categories:

1. Quantifying wetland extent and distribution;

2. Quantifying the current status and condition of wetlands on a regional scale;

3. Summary indices of wetland condition;

4. Defining nominal and subnominal wetlands;

5. Detecting trends in wetland condition through time on a regional scale; and

6. Diagnostics for identifying plausible causes of declining or improving wetland condition.

Each of these topics is discussed in turn in the subsequent subsections. Hypothetical examples are included of the types of summary outputs expected.

It is important to remember that EMAP-Wetlands is designed to address questions relating to regional populations of wetlands, **not** individual sites or specific cause and effect relationships. The results from the program will **not** answer questions, such as

- What is the impact of discharges from industrial plant "x" on local wetland quality?

- Are excess contaminant inputs the **cause** of low bird densities in wetland "y"?

In addition, the program outputs will apply specifically to the defined EMAP-Wetlands target population, i.e., vegetated wetlands included in the modified Cowardin classification that can be identified using aerial photography and the other landscape description techniques to be employed at Tier 1 (see Section 3.4). Regional estimates of wetland condition, based on the field measurements at the Tier 2 sites, are further restricted, and apply only to those wetlands in the Tier 1 target population that could be accessed for field sampling.

Conventional parametric statistical techniques have a number of underlying assumptions, many of which are often inappropriate for environmental data. For this reason, all data analyses, including routine data summaries, regression analyses, and multivariate analyses, will be conducted using resistant/robust alternatives as well as conventional statistics. Results from these alternative approaches will be compared.

If similar, results from conventional statistics will be reported. If different, reasons for these differences will be examined and will determine which statistical results are most appropriate given EMAP-Wetland's objectives. In addition, prior to all analyses, data distributions will be examined to (1) identify outliers and (2) evaluate the need for data transformations. Robust analyses will also be used to identify data outliers in multidimensional space.

The analysis and interpretation of the EMAP-Wetlands data will be guided by the conceptual and quantitative models of wetland components and processes described in Section 4.1.

6.1 QUANTIFYING WETLAND EXTENT

How many acres of wetlands are there in the United States, in total and for each major wetland class? Where do they occur? What proportion of the landscape do they cover? Answers to these questions are available from the USFWS's NWI (Frayer et al. 1983). Because of EMAP's probability-based design, answers could also be obtained as part of EMAP-Wetlands (following completion of the EMAP Tier 1 landscape description; see Section 3.4). Cooperative efforts between the NWI and EMAP-Wetlands will result in joint reporting on the extent of U.S. wetlands after the year 2005. The specific statistical procedures for combining these sampling frames have not yet been defined, however (see Section 3.2). Thus, the following describes only the basic EMAP-Wetlands methods for estimating wetland extent. These estimation procedures may be modified slightly depending on the final Tier 1 design.

As part of the landscape descriptions conducted in Tier 1, the numbers and areas of wetlands, by wetland class, will be measured within each of the 40-hexes established on the base EMAP grid points (Sections 3.1 and 3.4). For the base EMAP grid, these landscape description units represent $1/16^{th}$ of the total land area of the United States (see Figure 3-2). As a result, the total number (N) and area (A) of wetlands, for an individual wetland class, r, or for all wetlands combined, can be estimated as follows:

$$N_r = 16 \sum_{i=1}^{S} n_{ri}$$

$$A_r = 16 \sum_{i=1}^{S} a_{ri}$$

where

> n_{ri} and a_{ri} are the measured number and area, respectively, of wetlands in the r^{th} wetland class within the i^{th} 40-hex and
>
> S is the set of units (in this case 40-hexes) in the sample or any subset of the sample, such as for a given region or geographic area of interest.

The above equations represent a specific application of the Horvitz-Thompson formula (Horvitz and Thompson 1952), which reduce all design features to specification of the sample inclusion probabilities (Overton et al. 1990). The inclusion probability for each sampling unit is a direct function of the sample selection procedure. In the case of the 40-hexes on the base EMAP grid, the inclusion probability for each 40-hex is the same, 1/16. In calculations, inclusion probabilities are frequently converted into sample weights (w) equal to the inverse of the inclusion probability; in this case, w = 16 for each of the 40-hexes. Often, weights vary among sampling units, with w_i identifying the weight for the i_{th} sampling unit. The generalized Horvitz-Thompson estimation formula is then

$$T_y = \sum_{i=1}^{S} w_i y_i$$

for the estimated total value (T) of a given attribute, y. The estimated variance on T_y is as follows:

$$V(T_y) = \sum_{i=1}^{S} y^2_i w_i(w_i-1) + \sum_{i=1}^{S} \sum_{\substack{j=1 \\ j \neq i}}^{S} y_j w_j(w_i w_j - w_{ij})$$

where

w_{ij} is the inverse of the second-order inclusion probability, i.e., the probability that two specific sampling units, i and j, are included in the sample.

Procedures for estimating w_{ij} and variations on this basic approach to resource inventory estimation are discussed in Overton et al. (1990). Special studies are planned to evaluate the sensitivity of Horvitz-Thompson estimators to outliers, to the empirical distribution tails, and to the metric of analysis (e.g., untransformed versus transformed data). Modifications of the standard Horvitz-Thompson formulae will be considered, as needed, to develop analytical techniques that are more resistant to outliers and highly influential data points.

Using the Horvitz-Thompson formulae (or appropriate modifications), estimates of the number (for discrete wetlands) and area (for both discrete and extensive wetlands) can be calculated from Tier 1 data. The results can be summarized by wetland class or by any combination of wetland classes of interest, and for any geographic subdivision (e.g., EPA regions; Figure 2-3) or spatial partitioning of the United States. The outputs will be summarized both in tables and figures (e.g., Figure 6-1).

6.2 QUANTIFYING WETLAND STATUS

The Horvitz-Thompson formulae also provide the primary basis for regional estimates of wetland condition. Each wetland sampled at Tier 2 is assigned a weight (w_i), determined by the Tier 2 sample selection procedure. Using the Horvitz-Thompson formulae, modified as appropriate for the population parameter of interest, the results from the EMAP-Wetlands field survey can be expressed as:

- Population totals (e.g., the estimated total acreage of wetlands dominated by the vegetation indicator genus *Phragmites*, known to occur primarily in disturbed wetlands);

- Population means or medians (e.g., the average rate of sediment accretion or the mean percent dominance of the indicator genus *Phragmites*);

- Population quartiles or other percentiles, if the tails of the variable distribution are of greater interest than the population mean or central tendency;

- Estimated percent, number, or area of wetlands with indicator values above or below selected criteria (e.g., the percentage of wetlands with concentrations of chemical contaminants in the sediments above detectable limits); or

- Cumulative distribution functions, allowing the viewer to select any criteria or population percentile of interest (see Figure 6-2a).

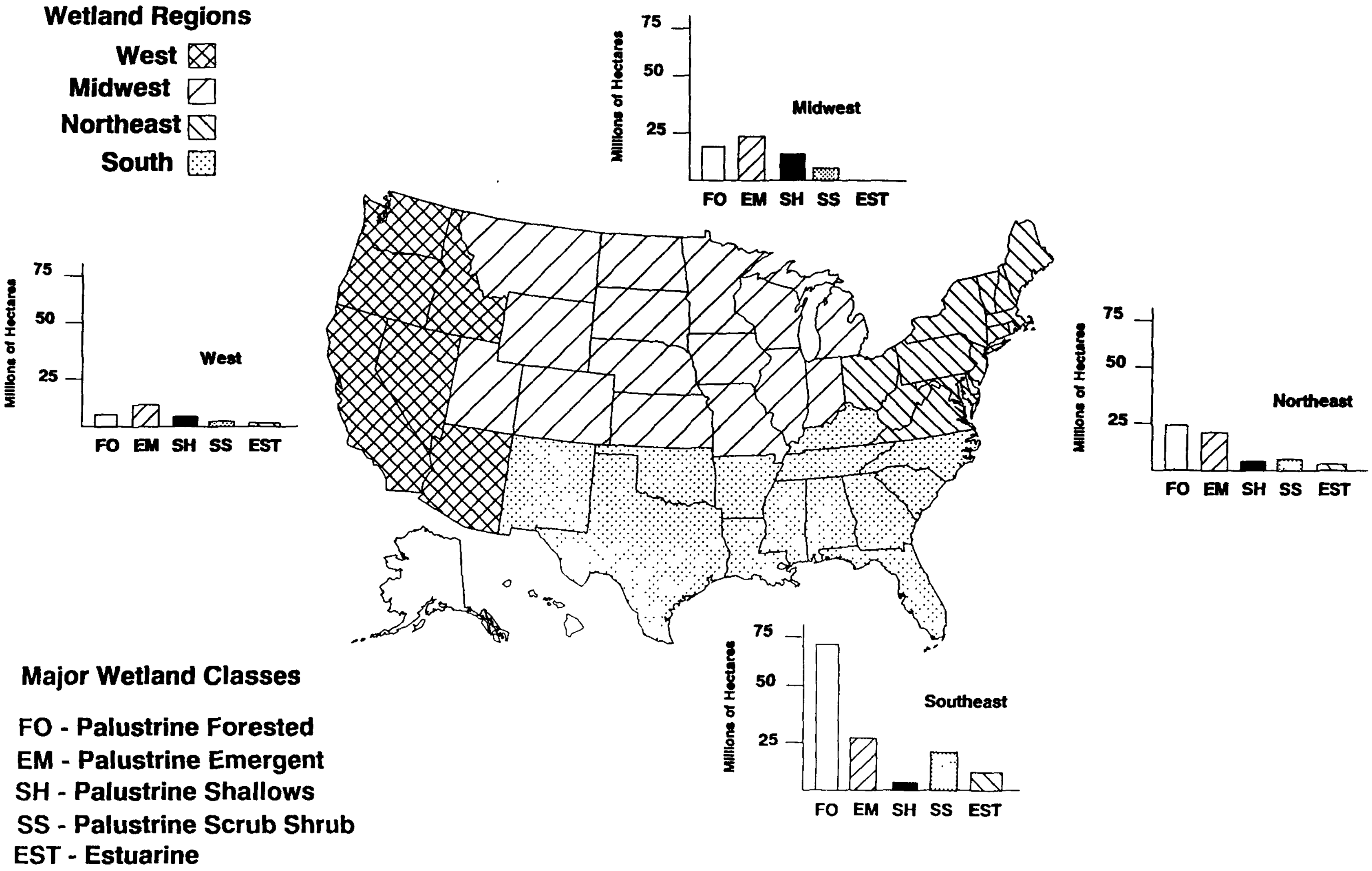

Figure 6-1. Hypothetical example -- Regional wetland surface area by major wetland class.

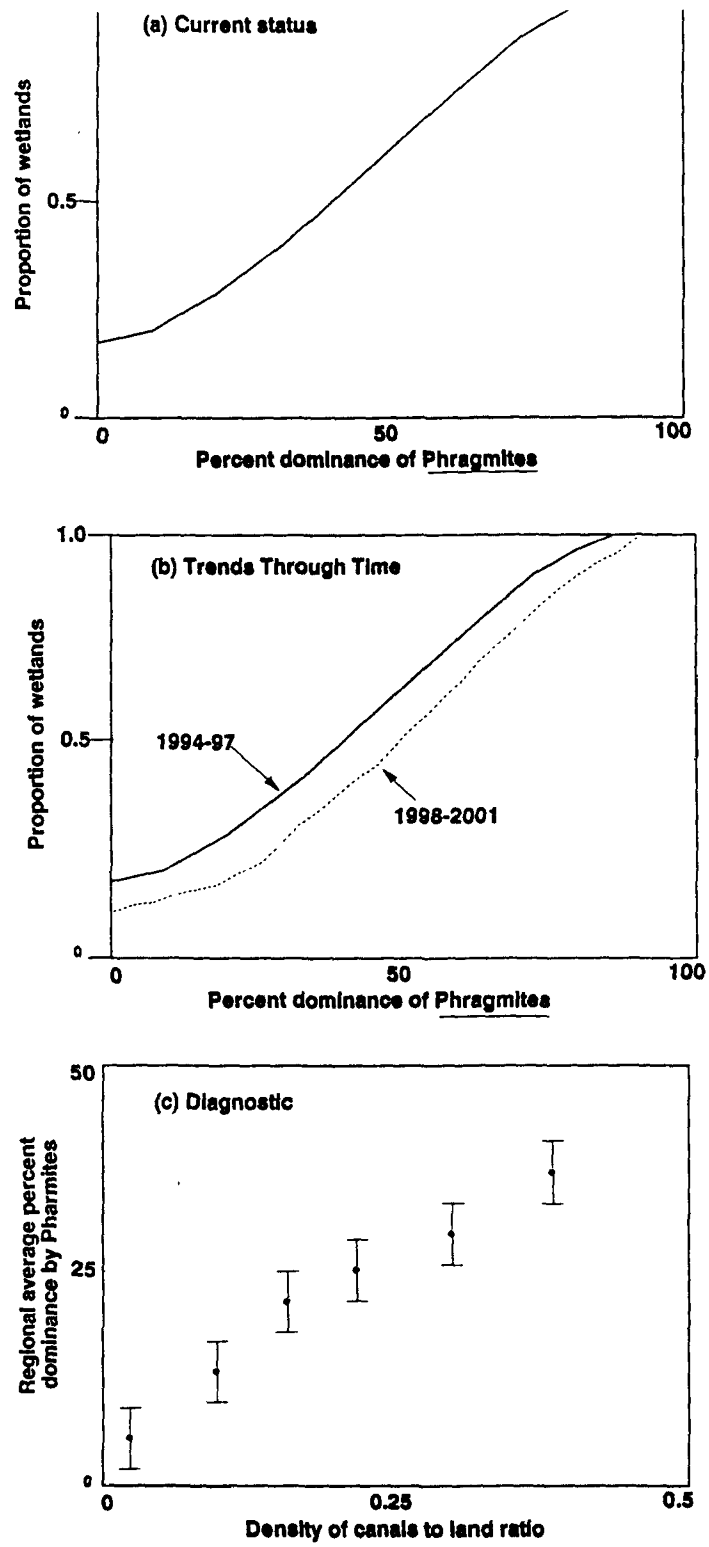

Figure 6-2. Hypothetical example -- Vegetation percent dominance of *Phragmites* spp., as an indicator of wetland of disturbance: (a) *regional cumulative* distribution function to assess current status; (b) shifts in the cumulative distribution function over time to evaluate regional trends; and (c) association between the regional average percent dominance (and 95% confidence interval) by aggregated EPA regions and the regional average density of canals to land ratio, as an example of one potential diagnostic analysis.

As for estimates of wetland extent, regional summaries of indicator values can be calculated for all wetlands, for individual wetland classes or groups of wetlands, and for any spatial subdivision (e.g., region) of interest. Thus, an almost infinite series of questions can be addressed, for example:

- How many wetlands are dominated by vegetation taxa indicative of disturbance (e.g., *Phragmites* spp.)?

- What proportion of the U.S. wetlands have detectable levels of pesticides in their sediments and in what areas of the country are these wetlands most frequently located?

- What types of wetlands have, on average, the highest ratio of exotics to native plant species?

- What EPA regions have the smallest percentage of forested wetlands with low levels of sediment accretion (< 1 cm/yr)?

Examples of the expected types of program outputs are presented in Figures 6-2a and 6-3a, using hypothetical data sets.

Variances associated with each population estimate will also be estimated using the Horvitz-Thompson formulae (or the modified Horvitz-Thompson formulae). Higher variances result from (1) smaller sample sizes, (2) higher variability in the measured indicator values, and (3) greater variation in w_i among wetlands. Indicator measurements will be conducted during an index period and at a specific index location to minimize the within-wetland indicator variability (see Section 5). To the degree possible, variations in inclusion probabilities among wetlands will be minimized in designing the final Tier 2 sample selection procedure (Section 3.5). Sample sizes can be controlled by the level of data aggregation used during data analysis. As noted in Section 3.5, generally $\geq$ 50 samples are needed per population subset of interest (e.g., for a particular wetland class or region) to obtain population estimates with reasonable levels of precision.

If the within-wetland indicator variability (as measured during the index period and at the index location) is substantial relative to the regional population variation, then the estimated cumulative distribution function (cdf) may have appreciable bias in the tails. More generally, any source of extraneous variation will cause some bias. The cdf of the observations is the convolution of the cdf of the population and the cdf of the extraneous variation source, and tends to be flatter than the population cdf. When such extraneous variation is present, it is important to identify this component of the distribution and to account for it in the analysis. In some cases, it can be accounted for in confidence limits; in other cases, removal may be preferred. This removal is referred to as deconvolution, and the development of satisfactory methods for deconvolution is a high priority research topic for the EMAP Design task group.

While direct statistical summaries of the data collected are relatively straightforward, in many cases they may not be sufficient for data interpretation. For example, the number of species co-occurring within a given ecosystem typically increases with the size and physical diversity of the system. For some purposes, we may prefer to present regional population estimates of species richness that have been adjusted for among-system differences in wetland size and physical diversity. The Tier 2 sample of wetlands will be surveyed over a period of four years, with one-fourth of the sites sampled each year (see Figure 3-3). Regional estimates of wetland status will be based on all sites and all four years of data. Adjustment of the sample data for inter-annual variability, e.g., resulting from natural climatic fluctuations, may yield more precise estimates of regional wetland condition. In both examples, we want to normalize the data relative to some standard, e.g., the expected number of species for a wetland of a given size and physical diversity, or for average climatic conditions (e.g., average rainfall).

The optimal approach for normalizing the EMAP-Wetlands data will likely vary for different indicators. In addition, some indicators will benefit more than others from adjustments of the raw sample data, in terms of increased precision or interpretability of the survey results. As part of the EMAP-Wetlands pre-implementation studies (analyses of existing data sets, simulation studies, and field pilots and demonstration studies; see Section 2.6), specific procedures for data normalization will be developed and tested.

Two key aspects of such analyses are (1) the use of reference sites to establish a baseline for comparison and (2) class specific model(s) that quantify the relationship between the indicator of interest and the wetland characteristics and (or) climatic factors associated with indicator variations. The models may be theoretical (if no data exist for model calibration), empirical, or mechanistic, although empirical models will be the primary model type. Data used for model calibration will be representative of the natural range of conditions expected within EMAP-Wetlands, and consistent with the EMAP-Wetlands field sampling protocols, but need not have been collected as part of the EMAP-Wetlands program. In many cases, the necessary data will be collected at the EMAP-Wetlands reference sites. Statistical techniques to be explored for model calibration include multiple regression (Kleinbaum and Kupper 1978), ordination analyses in combination with multiple regression, Bayesian approaches to incorporate expert judgement or to combine multiple data sources (Berger 1985), and robust multivariate analysis alternatives to each of the above to evaluate the sensitivity of the results to outliers and influential data points.

The outputs from these analyses, i.e., the normalized or adjusted values for the indicator, are then used as the basis for regional population estimates, using the same formulae as described above for the indicator measurements. Variance estimates, however, must be modified to incorporate both the sampling uncertainty, as above, and the added uncertainty associated with adjusting the data (i.e., the model uncertainty).

Often, the models will be calibrated based on data for undisturbed or minimally disturbed reference sites. Comparisons between observed and predicted values for a site provide, in this case, a measure of the deviation of the system from the expected or anticipated indicator value, potentially in response to external stressors. Thus, Figure 6-3a, for example, which presents hypothetical regional estimates of the mean number of bird species per wetland, could be modified to show the regional average **deviation** between the observed and expected number of bird species per wetland, based on wetland size and physical diversity, as illustrated in Figure 6-3b. Issues related to the use of reference sites and adjustments for natural sources of variability to detect effects from external stressors are explored further in Sections 6.3-6.4 and 6.6, respectively.

6.3 INDICES OF WETLAND CONDITION

The outputs from EMAP-Wetlands must be both scientifically valid and easily interpreted by policy analysts and decision makers. The need to develop data summaries useful for policy assessments requires innovative approaches to data analysis. The proposed use of summary indices of wetland condition and the classification of wetlands as nominal (healthy) versus subnominal (unhealthy) (Section 6.4) is in response to this need. The objective is to internalize, to the degree possible, scientific expertise and interpretation within the data analysis process, making the final outputs more directly interpretable by non-scientists and individuals without specialized expertise in wetland ecosystems. Both of these data analysis techniques are still in the conceptual stage, and will be the subject of substantial future research and evaluation.

For the purposes of this report, the term index refers to a mathematical aggregation or combination of a number of different, individual indicators to obtain a single value or index [Messer (1990) in Hunsaker and Carpenter (1990)]. Indices, therefore, reduce data for multiple, often highly diverse variables into a single quantity or summary metric of ecological condition. In this manner, complex information can be more easily conveyed to and interpreted by nonscientists. Indices are expected to provide the primary basis for linking indicator measurements to evaluations of the EMAP-Wetlands assessment endpoints (productivity, biodiversity, and sustainability).

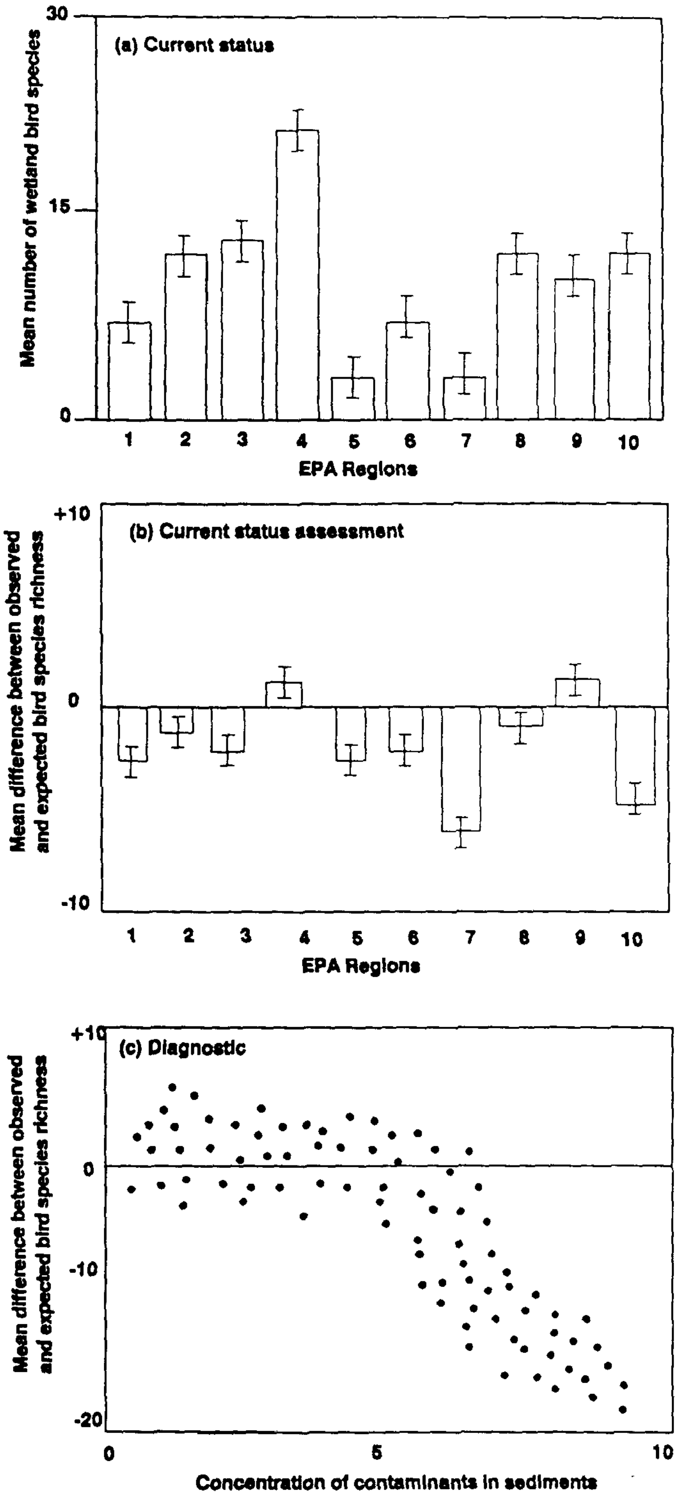

Figure 6-3. Hypothetical example -- Status and trends in wetland birds: (a) mean number of bird species observed per wetland (and 95% confidence interval), by EPA Region, to assess current status; (b) mean deviation (and 95% confidence interval) between the observed and anticipated number of bird species on a wetland, by EPA Region (negative numbers indicate fewer species were observed than expected for a wetland of that size and physical diversity), as a second-order analysis of current status; and (c) the deviation between the observed and expected bird species richness at each site in Region 1 as a function of the measured contaminant levels in wetland sediments, as an example of one potential diagnostic analysis.

We do not currently have indices of wetland health, which are widely accepted in the scientific community and have been tested on regional scales. The development of such indices is, therefore, a major research task planned within EMAP-Wetlands. Approaches to index development will include all of the following: (1) literature reviews, (2) analyses of existing data sets and simulations to explore alternative indices, (3) scientific review and input in workshops, (4) field testing and refinement during pilot and demonstration studies as well as EMAP-Wetlands implementation, and (5) determination of variability. It is highly likely that procedures for summarizing the program results, including the use of indices, will evolve and improve as program implementation proceeds. As noted in Section 9, the individual values for each indicator will be permanently maintained in the EMAP-Wetlands data base, allowing for the back-calculation of any new indices proposed at a later date.

Because the development of wetland indices is at a very preliminary stage, the following provides only a general overview of key concepts. More detailed reviews of the properties and use of environmental indices can be found in Ott (1978) and Warren-Hicks and Messer (in prep.). Washington (1984) reviewed indices used in water quality studies; Walworth and Sumner (1986, 1987) reviewed indices used to describe the nutritional status of plants and soils.

Generally, the construction of an index occurs in three steps (Warren-Hicks and Messer, in prep.; Figure 6-4):

1. Selection of the individual indicators to be used,

2. Calculation of the subindex for each indicator, and

3. Aggregation of the subindices into an overall index.

Subindices serve two primary purposes:

1. To express diverse indicators, which often have different units of measurement, on a common scale and

2. To account for natural variations in indicator values, associated with different wetland classes, different regions, or individual site-to-site variability.

Natural variations in indicator values are usually addressed by defining an **anticipated** value or distribution of values for a wetland of given type, e.g., within the wetland class or region of interest. In some cases, empirical models may be used (as discussed in Section 6.2) to account for individual wetland features or climatic factors that may influence natural site-to-site variations in indicators. The anticipated value(s) may be defined using data from reference sites, historical records, experimental data, theoretical considerations, and (or) expert judgement (see Section 2.2).

The subindex scale is used, then, to express the observed deviation of the indicator from the expected value, on either an ordinal or cardinal scale. For example, wetlands may be rated on a scale of 1 to 5, with 1 representing consistency with the anticipated value and 5, the maximum deviation from the anticipated value. For some indicators or indices, it may be desirable to reduce the subindex scale simply to a yes/no variable, rating each indicator as nominal (consistent with the expected value) or subnominal (not consistent with the expected or reference value)(see Section 6.4).

The assignment of a value for the subindex, for a given wetland (and wetland indicator), will be based on a set of objective criteria (e.g., statistical deviation from the observed distribution of values in reference wetlands). Formally defining these objective criteria is not a trivial task, however. Some existing indices, such as the Index of Biotic Integrity developed by Karr et al. (1986) for stream systems in the Midwest, rely

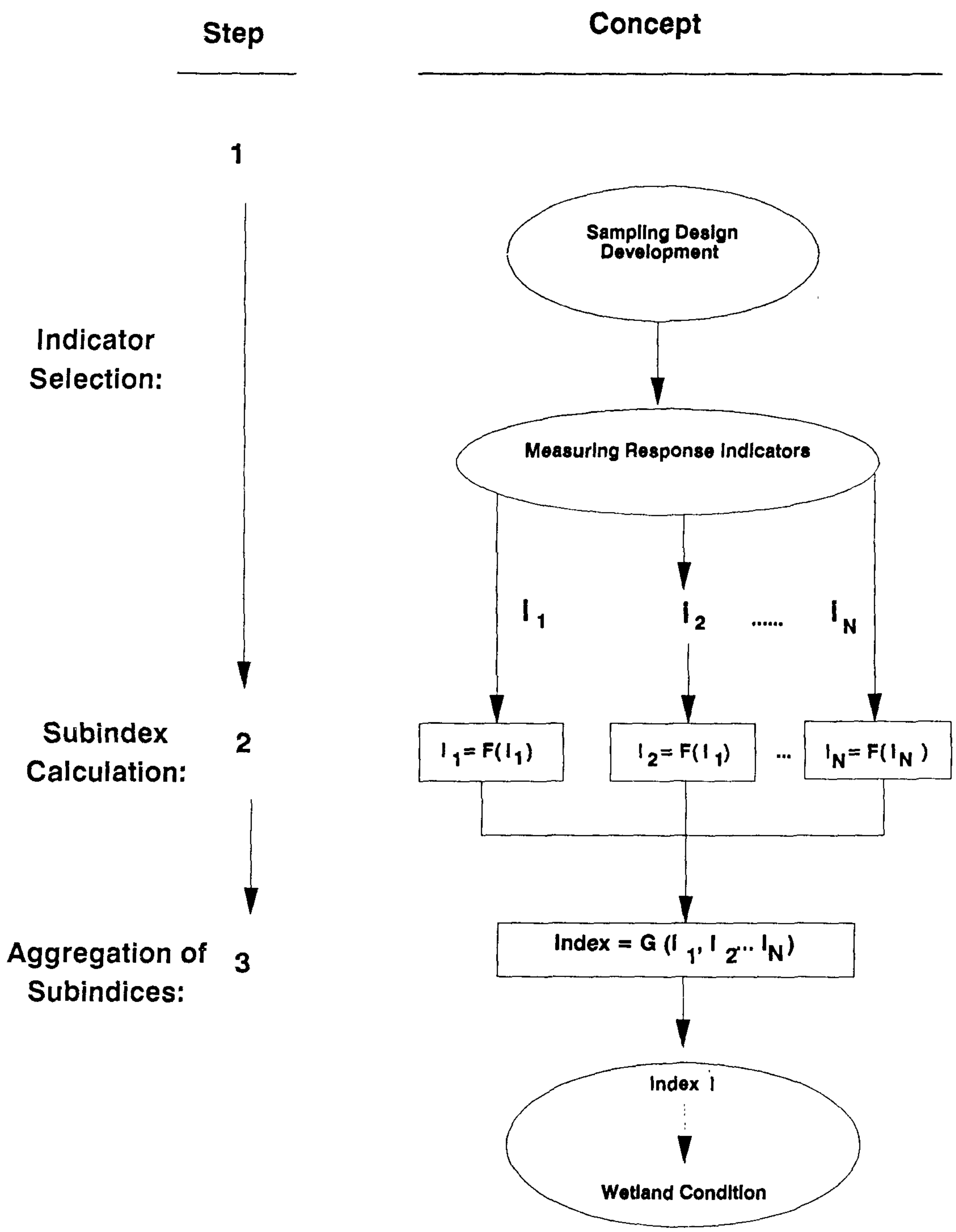

Figure 6-4. Construction of an index. F and G represent generic functions. [Sources: Warren-Hicks and Messer, in prep.; Adapted from Ott (1978)]

on expert judgement to assign subindex values. The use of experts, however, is likely to introduce inconsistencies, especially since the specific experts involved will change over the course of a long-term monitoring program such as EMAP. Thus, the approach to be pursued is to use experts (and expert consensus techniques such as the Delphi technique) to **establish** the specific **objective criteria** and assignment rules to be applied for each indicator subindex.

The third critical task is deciding how best to aggregate the subindices. Alternatives include addition, multiplication, maximization, minimization, and the use of nonlinear functions (Ott 1978). The selection of the aggregation scheme obviously has a large effect on the responsiveness of the index to environmental change, and each operation has advantages and disadvantages.

Ideally, we would like the index construction to reflect the thought process that would be used by a wetlands expert to evaluate wetland condition. Different experts, however, would conduct such an assessment differently. Thus, like the economic indices used to evaluate the U.S. economy, several indices of wetland condition may be developed and reported, each one examining slightly different aspects of wetland health (e.g., the three major assessment endpoints). Important characteristics of good indices include (Warren-Hicks and Messer, in prep.):

- Indicator diversity -- incorporating indicators that cover all important aspects of wetland structure and function;
- Uniformity in response -- changing in a consistent manner in response to comparable changes in wetland condition in different wetland classes, different regions, and for different types of stress;
- Reasonable precision -- minimizing, to the degree possible, the magnification of uncertainties resulting from aggregating indicators (The uncertainties associated with index calculations will be quantified.);
- Responsiveness to environmental stress -- providing for early detection of degrading or improving wetland condition, over time and space; and
- Interpretability -- facilitating the communication of EMAP-Wetland results to a broad audience.

6.4 DEFINING NOMINAL AND SUBNOMINAL WETLANDS

For the most part, wetland changes in response to stress occur along a continuous scale. Nevertheless, decision makers often ask for the bottom line: Is the wetland healthy (in good condition) or not? What percentage of the wetlands in a given region are in satisfactory condition? To address these needs, procedures will be developed in EMAP-Wetlands to classify systems as nominal (healthy) and subnominal (unhealthy).

The framework for classifying wetlands as nominal versus subnominal has been introduced in the prior sections. Specifically, the measured wetland indicators will be compared to **anticipated** values or ranges for each indicator, where the anticipated values are based on measurements at reference sites, historical records, experimental data, theoretical considerations, and (or) expert judgement. In addition, empirical models or other quantitative tools may be used to account for natural site-to-site variations in indicator values. Finally, the aggregated indicators, expressed as wetland indices, also provide a basis for evaluating wetland condition.

Major issues remain, however. How much can an indicator measurement, or index, deviate from the expected value before the wetland is classified as subnominal? What constitutes a biologically significant or policy-relevant difference? How do we resolve apparently conflicting results when they arise, if some indicators suggest that conditions are nominal while others are subnominal?

The characteristics required for a wetland to be classified as nominal may vary depending upon the assessment endpoint of interest. As an extreme example of this dichotomy, forested wetlands may be valued both for their timber production (productivity) and as habitat supporting a diverse fauna and flora (biodiversity); the wetland attributes used to define good conditions for these two uses would be markedly different. As a result, a given wetland may be nominal for one use or value, yet subnominal for others. In establishing the criteria for nominal and subnominal, therefore, the standard for comparison must be clearly defined, and multiple classifications may be necessary for conflicting wetland values.

The approach to classifying systems as nominal versus subnominal will rely on statistics as well as expert judgement. Several types of statistical analyses may yield information useful in selecting the final classification criteria. For example, sites considered by experts to be nominal and sites considered subnominal will be sampled during the field pilot studies (Section 2.6.2). Discriminant analyses, using the full suite of indicators measured in the two types of systems, may aid in identifying key indicators and indicator values associated with the nominal and subnominal classes. Indicators may be considered subnominal if the measured values fall at the extremes (e.g., $< 10^{th}$ percentile or $> 90^{th}$ percentile) of the indicator distribution measured in reference wetlands (Figure 6-5a). Alternatively, logical "break-points" may be evident in the regional distributions of indicators measured during EMAP that may be appropriate for partitioning nominal and subnominal systems (Figure 6-5b). All available sources of information will be reviewed and considered by groups of experts as part of the process of establishing the nominal/subnominal classification. In addition, by reporting and maintaining the full cumulative distribution function for each indicator and index in the EMAP-Wetlands data base, any future revisions of the nominal/subnominal classification criteria will be facilitated.

Assessment of a wetland as either nominal or subnominal will rely not on any single indicator, but on the full set of monitored response, exposure, habitat, and stressor indicators. Inconsistencies that may occur in indicator signals may require additional categories of wetland condition. Healthy wetlands, as defined in Section 2.2, are characterized by both the occurrence of attributes considered indicative of a healthy sustainable resource and the absence of known stressors or symptoms of stress. Based on these two criteria, four scenarios may arise in assessing wetland condition (Figure 6-6):

1. The wetland is classified as nominal if the response indicators are within a normal range and the exposure indicators fall below the expected thresholds for damage.

2. The wetland is classified as subnominal if the wetland's response indicators fall outside of their normal statistical range and the exposure indicator values exceed reported thresholds for effects.

3. The wetland is labelled as experiencing an incipient problem if the response indicators are within normal statistical ranges but one or more of the exposure indicators exceeds the threshold for damage. Such results may be indicative of an emerging environmental problem.

4. If the wetland's response indicators fall outside of their normal range, but none of the monitored exposure indicators exceed known thresholds for damage, the system is recorded as having an unidentified problem.

Estimates of the numbers and proportion of wetlands classified as nominal and subnominal within a given region must also be accompanied by an evaluation of our confidence in these results. Uncertainties arise both from the EMAP-Wetlands sampling frame and from the nominal/subnominal classification. The

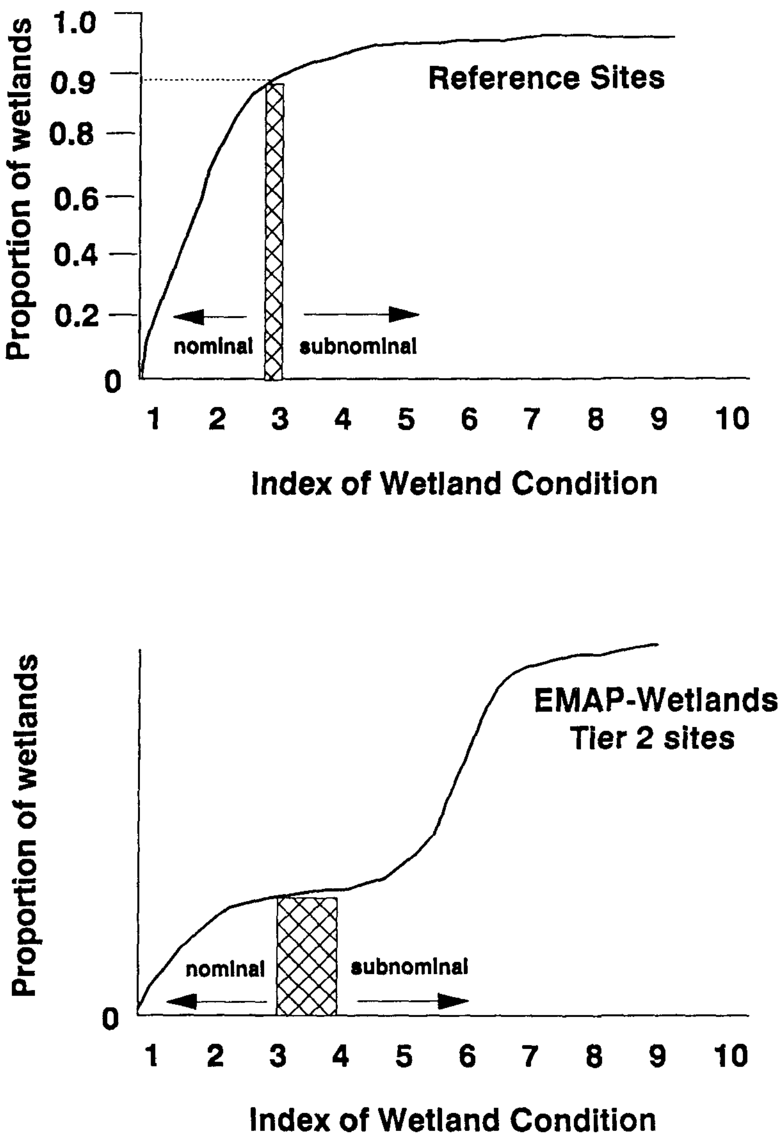

Figure 6-5. Examples of the use of cumulative frequency distribution for (a) reference wetlands and (b) EMAP-Wetlands Tier 2 sites, to evaluate criteria for classifying wetlands as nominal and subnominal.

Response Indicators Within Normal Range?	Exposure Indicators Exceed Threshold for Damage? YES	NO
YES	Incipient Problem	Nominal
NO	Subnominal	Unidentified Problem

Figure 6-6. Categories of wetland health.

classification errors will be difficult to fully quantify; thus innovative approaches summarizing both qualitative and quantitative uncertainties are needed.

6.5 DETECTING TRENDS THROUGH TIME

Changes or trends in wetland status over time are also of primary interest for EMAP-Wetlands. As was the case for assessments of current status, the flexibility of the EMAP-Wetlands design allows a wide range of questions to be addressed:

- Have the extent and quality of riparian wetlands in the west changed over the last 10-20 years, based on measures of the areal extent of vegetative cover and vegetation community composition?

- Have sediment accretion rates in wetlands increased or decreased? If so, to what degree, and in which regions and wetland classes?

- Is the number of nominal wetlands in the U.S. increasing or decreasing? How many nominal wetlands are lost (or gained), on average, each year?

- What regions and wetland classes have experienced improvements in wetland extent and condition in recent years? In which regions have wetlands continued to decline?

- o *Are the rates of improvement (or decline) in wetland condition greater in some areas of the country than in others, or for some wetland classes than for others?*

A number of techniques are commonly used for detecting trends in environmental data, including both parametric (conventional and robust) and non-parametric methods (e.g., Hirsch et al. 1982, Pankratz 1983, Gilbert 1987, Loftis et al. 1989, Wedepohl et al. 1990). Most analyses, however, have focused on single sites, often with multiple measurements per site per year, and on changes in the mean value or central tendency over time. In contrast, for EMAP-Wetlands, methods must be developed that (1) assess changes at a regional-scale and (2) consider other parameters in addition to the mean or central tendency. For example, an increase in indicator variability may be an important signal of ecosystems responding to stress. Likewise, regional means may be relatively robust; changes in regional wetland status are more likely to be detected at the tails of the distribution (e.g., in the most sensitive wetland systems) than in the mean or median indicator value.

Trend detection techniques that are specific to the EMAP interpenetrating design are being developed by the EMAP Design task group (Overton et al. 1990). Analyses will focus on the cdf as the primary tool for summarizing population descriptions and assessing change. Patterns in the data can be detected by examining changes in regional cdfs over time for each indicator (e.g., Figure 6-2b). Differences between two time periods can be tested with a chi-square test of homogeneity, modified to account for variations in the Tier 2 weights among wetlands. Because of the repeat visits to each site incorporated into the interpenetrating design, paired analyses can be used, which increase the power of the tests by eliminating variations that result from population sampling. Statistical comparisons can be conducted for population quartiles, medians, or any other population characteristics of interest. Trend statistics can also be calculated for individual components (e.g., individual sites). The distribution of these trend statistics within a given region will be examined visually, and also may be tested using meta-analysis (Reckhow et al. 1990).

An important consideration in selecting techniques for trend detection will be the test sensitivity or, in statistical terms, the power of the test. Statistical power is the probability that a hypothesis will be rejected given that the hypothesis is false. Generally, power increases with increasing departure from the hypothesis, that is, a large change is more likely to be detected than a small change. A statistical test of a particular hypothesis can be characterized by specifying the size of the test (probability of rejecting a true hypothesis) and its power function (probability of rejecting a false hypothesis as a function of the degree of departure from the hypothesis). Where choices among alternative methods of change and trend detection exist, the more powerful test will be preferred.

Of particular concern is whether the background indicator variable may be too high to achieve the desired trend detection goal (tentatively, 1-2% yearly change over a ten-year period). As part of the indicator selection process (Section 4), analyses of existing data together with data collected in the pilot and regional demonstration studies will be used to (1) quantify indicator variability, within site, between sites, among wetland types, and over time, and (2) evaluate the relationship between the expected background indicator variability and trend detection sensitivity (i.e., the magnitude of trend that can be detected over what time period at what significance and power). Indicators will be selected, and sampling protocols will be designed, to minimize, to the degree possible, background variability, thereby increasing the ability to detect regional-scale trends in indicators through time.

Examples of the types of summary outputs on resource trends to be prepared for the EMAP-Wetlands statistical summaries and interpretive report are presented in Figures 6-2b and 6-7.

6.6 DIAGNOSTICS

A final major issue in data analysis and interpretation is the identification of plausible causes for observed regional patterns and changes in wetland status. The data collected by EMAP-Wetlands will be

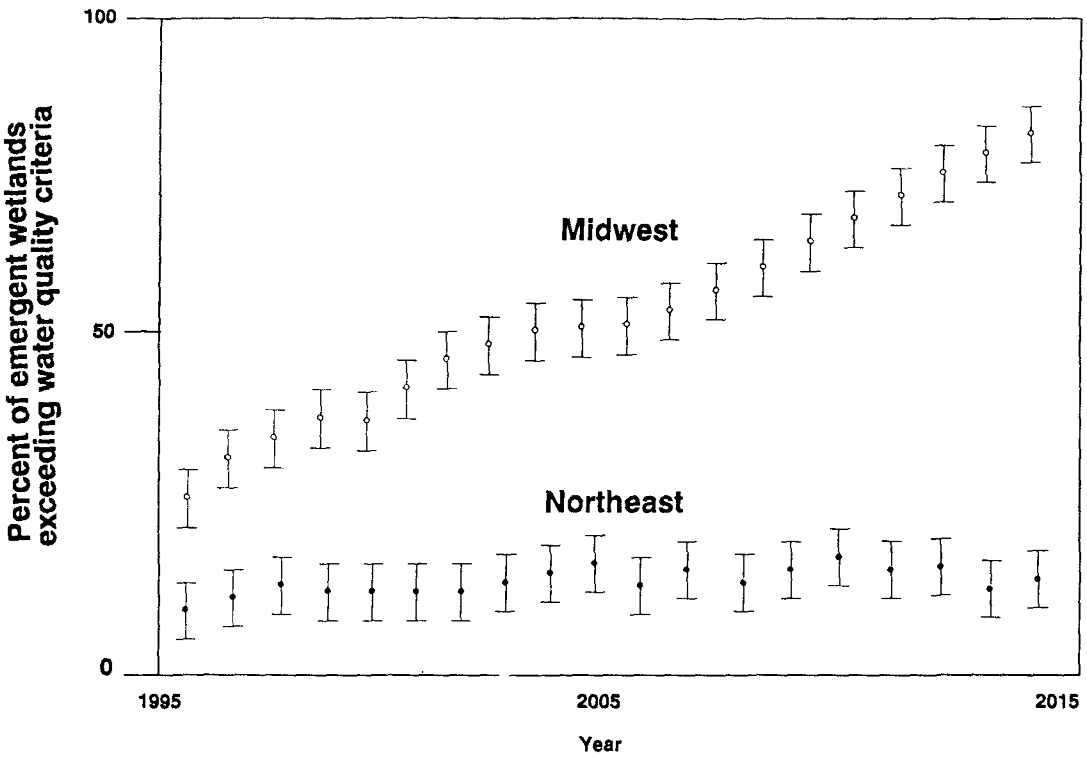

Figure 6-7. Hypothetical example -- Percentage of Palustrine emergent wetlands (and 95% confidence interval) that exceeds water quality criteria standards for toxic organics.

observational; thus, specific cause-and-effect relationships cannot be tested or proven. However, correlation analyses and simple diagnostics can be used to identify, on a regional scale, potentially important causes of nominal and subnominal conditions.

Graphical techniques and statistical association analyses [parametric (conventional and robust) and nonparametric] will be used to explore the relationships between indicators (or indices) of wetland condition (e.g., response indicators) and the measured exposure, habitat, and stressor indicators. Analyses will be conducted using data for individual sites, such as in Figure 6-3c, and by comparing subpopulation means or other summary statistics, as in Figure 6-2c. In many cases, weighted analyses may be appropriate, weighing each observation by the inverse of its inclusion probability in the sample. Relationships between wetland condition and indicators of stressors, exposure, and habitat will be examined both over space (e.g., regional patterns) and over time. The conceptual and quantitative models, developed as part of the indicator selection process to delineate important linkages among assessment endpoints, indicators, and major wetland stressors (Section 4.1; Figures 4-2 and 4-3), will be used as a guide for selecting analyses to be conducted.

Causal relationships, between wetland condition and possible stressors may be more evident if natural sources of indicator variability can be accounted for, either as additional variables in multivariate analyses or in separate analyses. As discussed in Section 6.2, empirical models may be used to predict **expected** indicator values in undisturbed or minimally disturbed wetlands as a function of important natural wetland characteristics and (or) climatic factors. The deviation between the expected and observed indicator values measured at EMAP-Wetland sites may then be used as a second-order indicator of wetland condition (see Figure 6-3c).

A particular concern for EMAP-Wetlands is to distinguish between trends caused by anthropogenic factors and natural wetland succession. Wetland succession is a widespread phenomenon occurring in boggy areas and the prairie potholes of the midwest as well as in riparian areas in the arid west and southeastern United States. In most cases, natural succession is a slow process, while anthropogenic changes occur more rapidly. Regardless, the development of diagnostic techniques for separating natural and anthropogenic causes for wetland trends is a major challenge and issue currently being considered by EMAP-Wetlands. Stratification of wetlands by successional phase during data analysis may be one approach; other approaches will be developed and tested as part of program planning and pre-implementation studies. Long-term records of wetland changes at EMAP reference sites (one or more per region and wetland class) and other undisturbed wetlands (e.g., LTER sites), together with climatic records, will provide the basis for defining the range of response and trends associated with natural wetland fluctuations and succession.

Using the results from the above analyses, the ultimate objective is to estimate the relative importance of each major wetland stressor on a regional scale, as illustrated in Figure 2-6. Thus, Tier 2 wetlands considered to be in subnominal condition will be further classified as to the most plausible cause for the observed poor condition. The approaches for developing and testing these diagnostic tools will be similar to those described in Section 6.4 for the nominal/subnominal classification. Statistical results as well as expert judgement will be used to define objective classification criteria. Initially, in the early stages of EMAP-Wetlands implementation, large numbers of wetlands are likely to be classified as cause unknown. Through time, as a result of both additional monitoring data and more detailed process-level research in Tiers 3 and 4, the size of the unknown category should decline.

7.0 LOGISTICS APPROACH

7.1 LOGISTICS IMPLEMENTATION COMPONENTS

EMAP proposes to collect ecological information annually, from a large number of sampling sites throughout the United States. Implementing a national program of this magnitude will require detailed comprehensive logistics planning. Logistical considerations include coordination and oversight of all implementation support activities (e.g., access permission) and the actual data collection activities. A logistics plan will be developed prior to the start of implementing field activities to assure that they meet the goals of the program. Regional logistics plans will be updated annually. The logistics plan will address all elements given in Table 7-1 as specified by the U.S. Environmental Protection Agency (1990b).

Element 1. Overview of Logistics Activities - Summarize the types of activities required to complete the project. Maintain a timeline or Gantt chart showing all critical path milestones (e.g., project design, indicator selection, site selection, access permission, reconnaissance, procurement, methods selection, development of standard operating procedures, and resolution of specific quality assurance issues). Show required deliverable products such as plans, manuals, and reports. Also provide logistics budget summaries.

Element 2. Staffing and Personnel Requirements - Describe the number of personnel and the organizational structure necessary to accomplish project objectives. Define who is responsible for staffing and interagency and teaming mechanisms. Consider work schedules to determine whether extra positions should be created or whether existing personnel should work overtime. Create a contingency plan for replacing staff members when necessary. Identify key personnel and provide plans for retaining them.

Element 3. Communications - Address communications among field crews, laboratory crews, and supervisory personnel and between EMAP participants and any local organizations who should be informed of EMAP field activities. Also include plans for tracking samples, data, crews, and equipment and supplies. Discuss how field crews should interact with the public or with the media. Explain how approved changes in standard operating procedures will be documented and communicated for implementation.

Element 4. Sampling Schedule - Based on project, indicator, and statistical design or other program requirements, devise an efficient schedule for field activities. Consider geographical sampling windows within geographical areas and other factors such as climate and site access constraints.

Element 5. Site Access - Address issues related to gaining access to sampling sites including scientific collection permits, if required. Develop a list of local contacts to discern property ownership, jurisdiction, and the best site access methods. Address plans to obtain appropriate access permission and applicable collection permits. Consider how to coordinate the activities of multiple resource groups working in the same area. Discuss ways to arrange long-term access rights, track changes in ownership of private sites and management of public sites, notify owners and managers before revisiting the sites for future monitoring, and provide contingency plans in case of future failure to obtain re-access permission.

Element 6. Reconnaissance - Define criteria for selecting base operation sites (take into consideration personnel and technical support requirements), geographical location with respect to sampling sites, and time constraints imposed by sampling design or climate. Sampling sites identified as having potentially difficult physical or legal access should be visited during field reconnaissance. Additional resources needed for sampling should be identified if the access problem is due to physical conditions. If the access problem is legal, one last attempt should be made to obtain permission to sample.

Table 7-1. EMAP Logistical Elements for Implementation of a Monitoring Program.

Overview of Logistics Activities	Procurement
Staffing	Training
Communications	Field Operations
Sampling Schedule	Laboratory Operations
Site Access	Data Management Activities
Reconnaissance	Quality Assurance
Waste Disposal Plan	Logistics Review
Safety Plan	

Element 7. Waste Disposal Plan - Explain how chemical and biological wastes will be stored, transported, and disposed of safely and legally. Address what permits will be needed for storage, transport, and disposal of wastes.

Element 8. Safety Plan - Discuss how emergency situations will be evaluated and handled. Determine emergency contact personnel and what emergency services will be available in the field. Explain what procedures will be used to initiate search and rescue operations. List the training or other preventive measures required to conduct field operations safely. Indicate how this field safety plan will be developed in conjunction with laboratory, processing, and materials handling safety plans.

Element 9. Procurement and Inventory Control - Identify equipment, supply, inventory control and resupply, and services requirements of the field program and the processes by which they will be acquired and maintained. Determine where back-up equipment will be stored and how sites will be resupplied. Consider shipping regulations, especially for chemical and biological materials. Determine what analytical or other services will be needed and the best mechanisms for acquiring them. A procurement schedule should be provided for all items.

Element 10. Training Program - Describe who will prepare, review, and revise the field training and operations manual and the procedures for field measurements, sampling, sample handling, shipment, data recording, quality control, safety, waste disposal, and communications. Outline a schedule for the completion of these items. Describe training needs and identify who will conduct and review training. Address how personnel will be evaluated to ensure competency.

Element 11. Field Operations - Indicate the organizations that will perform each of the daily field activities. Describe how and when the daily field activities will be performed. Discuss and schedule the major events within field operations (i.e., mobilization, demobilization, and phase changes in sampling activities). Consider contingencies such as back-up personnel in the event of sickness. Require real-time evaluation to identify and resolve problems.

Element 12. Laboratory Operations - Indicate what organizations will be responsible for each type of sample preparation or analysis and for formulating each laboratory operations manual. If EPA conducts the activities directly, provide a development plan for providing appropriate laboratory facilities.

Element 13. Information Management - Describe any data management activities that might be affected directly by field operations. Establish guidelines for the timely and responsive transferral of information from field personnel to data managers. Indicate the groups that will be responsible for preparing and reviewing field data forms; provide a schedule for the completion of these forms. Develop a schedule for completion of the information management plan by the information management group.

Element 14. Quality Assurance (QA) - Describe who will provide input to the QA plan on field sampling, sample handling and preparation, sample shipment, sample disposition, and data management. A schedule for implementing the QA plan should be provided to the logistics team and included in the logistics plan. QA activities should be coordinated with other resource groups using similar methods to ensure comparability in the data collection. This effort should identify common methods and standards when possible.

Element 15. Logistics Review and Recommendations - For each year of study within each resource group, summarize logistics activities. Discuss how personnel will be debriefed to identify and resolve problems. Discuss pilot studies and associated methods evaluation experiments; present logistics data summaries within the full-scale project.

Field activities will begin in 1991 with a pilot program in the coastal salt mashes of Louisiana. Additional wetland classes and regions will be phased into the program in each of the following years. Additional information on the implementation schedule for the wetlands component of EMAP is presented in Chapter 12.

7.2 LOGISTICS ISSUES

The complexity of this program poses a number of logistics issues that will have to be addressed. Overlooking or ignoring apparently minor issues or details may eventually jeopardize the success of the program. These issues will be addressed fully in each of the regional logistics plans prior to the implementation of field activities. This can only be accomplished through long-range planning and coordination. A brief discussion of the major issues (staffing, access, and data confidentiality) is provided in the following sections.

7.2.1 Staffing

Due to the nature of the field data needed for indicator evaluation (Section 4), field personnel must have a high degree of expertise. They must have knowledge of plant and macroinvertebrate taxonomy, field sampling methods, and sample handling. Finding personnel with expertise in these areas will be a major challenge.

Regardless of the level of expertise, all field personnel will be required to undergo a training program. Training ensures that protocols are understood and provides consistency across the program. The training program will include field first aid, taxonomy of appropriate organisms, sample collection and processing, data entry, and will ensure participant familiarity with the quality assurance/quality control (QA/QC) project plan. There will also be a discussion on contingencies and strategies plus sampling exercises for QA/QC and time checks. The establishment of wetland method training centers in regional institutions or agencies with wetland expertise and facilities is being considered. Training is expensive but imperative to an effective and efficient sampling program. Training costs can be reduced in the long-term only by retaining staff. Therefore, retaining key personnel during nonfield seasons is critical to program continuity and cost effectiveness. Long-term agreements with contributing agencies and institutions to provide key personnel are essential to the resolution of this issue.

It is anticipated that a large and diverse collection of organizations will be contributing to EMAP monitoring activities. Various agencies (USWS, SCS), EPA regional offices, universities, state resource agencies, and other groups (e.g., The Nature Conservancy) have large pools of experienced personnel. Service from these groups may include wetland site selection and access, field data and sample collection, laboratory analysis, and data analysis. The mechanisms for acquiring the necessary services, responsibilities of the personnel, and chain of command will be addressed in the Logistics Plan.

7.2.2 Access

Obtaining access information and permission to visit sampling sites is a difficult and time consuming task. If land is owned publicly, approval must be obtained from the appropriate authority and permission may be conditional (e.g., upon the use of nonmotorized transport). Contingency plans for these conditions will have to be developed. If land is owned privately, each landowner will have to be contacted and written access permission will have to be obtained. Sample collection permits will have to be obtained from each state regardless of land ownership.

Gaining access permission to wetlands will be a major task, especially considering the stringent regulations regarding their management on private lands. Cooperation with local agencies that regularly address this issue will be essential. The Army Corps of Engineers (ACO), for example, maintains a realty division whose job is to acquire site access. Knowledge of access routes will require reconnaissance. The amount of time devoted to sampling a wetland site is dependent upon the physical access condition. Some sites may be accessible only by foot and some sites by watercraft. Each wetland identified as having difficult access should be visited prior to sampling to determine how sampling crews and gear can be transported to the sampling site and how samples can be transported adequately.

7.2.3 Data Confidentiality

Data confidentiality is an issue of particular concern to EMAP. Many landowners may be reluctant to permit access to wetlands from their property because they fear regulations and enforcement actions. Access is not a design constraint, and any denials by landowners could affect population estimates. Cooperating agencies within the Department of Interior (e.g., USFWS) often conduct field programs under an agreement of confidentiality with landowners. Data may have to be aggregated on a regional or population level to assure landowners and cooperating agencies that site-specific data will not be used against their interests. Agreeing to withhold certain information, however, is in direct conflict with the Freedom of Information Act and EPA's policy on data confidentiality. This issue has been addressed by Franson (1990), and the EPA Office of General Counsel is currently being consulted in this matter.

Protocols will be developed for the use of EMAP-Wetlands data by other EMAP participants. For example, written permission may be required to obtain data from the originators.

7.3 OPERATIONAL CONSIDERATIONS

Field operations include each of the daily activities (e.g., sample collection) plus major events (e.g., field base site changes) that will occur during the sampling period. Operational considerations that must be resolved prior to initiating monitoring activities include (1) base site technical support requirements (e.g., utilities, equipment storage, sample shipping facilities), (2) safety (e.g., travel itinerary, personnel medical information), (3) equipment and supplies (e.g., maintenance and repair gear, sample collection and preparation paraphernalia, transportation, communication, access to photocopier), and (4) resources (e.g., site access information, location of hospitals and hardware stores). In addition, contingencies for delays due to climatic conditions, equipment failure or unexpected obstacles must be determined.

A general logistics scenario is presented to demonstrate that the proposed field activities are logistically feasible within the allotted time frame. This is a general scenario and will be further developed as specific protocols for field measurements are determined. The scenario is based on the priority indicators (Section 4) and on the following assumptions:

- o The index period may vary among regions and wetland classes, but in most cases will be in mid to late summer, a sampling window of approximately 4 weeks.
- o The number of Tier 2 sites sampled per year will be approximately 800, and it will take 4 years to sample all Tier 2 sites.
- o The site selection is completely random and does not consider site access.
- o The majority of sampling will be done by foot, although in some wetland classes, motorized boats will be necessary.
- o The four-wheel drive vehicles will be used for site access and each sampling team will need a second vehicle for logistics support.
- o The field mobile laboratories will not be used and there will be a minimum of sample preparation in the field.
- o The samples requiring immediate laboratory analysis will be shipped to the appropriate laboratory by overnight courier the day after collection.
- o A field crew will consist of five people; four for field sampling activities and one for logistics support.

Based on these assumptions, a field crew of four people will be required to sample a wetland within a two-day period. Transit time between sites will require most of one day, and with one day off, a field crew could sample approximately three wetlands per week. Wetlands greater than approximately 20 ha and with difficult access will require additional time and (or) staff. A total of 60 to 70 field crews will be required to sample all 800 wetlands within the index period. Allowance for downtime due to weather and other factors will have to be considered in determining the actual number of field crews. Each field crew will be responsible for sampling 15-20 sites in an area approximately the size of Oregon. To organize and coordinate the activities of 60 to 70 field crews, 5 to 10 regional logistics centers will be developed across the Nation. These regional logistics centers could possibly be integrated to support the field activities of the other EMAP resource groups (Surface Waters, Near Coastal, Forest, Agroecosystems, and Arid Lands). A number of assumptions vary considerably depending on the region and the wetland class.

7.4 ORGANIZATION AND STRUCTURE

Coordinating the logistics activities (staffing, training, deployment, tracking, etc.) of 50 or more EMAP-Wetlands teams across the Nation will be very difficult. Regionalizing these logistics activities into various centers will be the most effective mechanism for conducting EMAP field operations. The EPA regions have first hand knowledge of the environmental conditions within their respective regions and will have a major role within EMAP, part of which could be in logistics. They represent the Agency's primary contact with the states, and are working with the states at the program level. Securing cooperation from the states for EMAP is essential because of requirements regarding collection permits and access permission. The EPA regions and states also have highly experienced field personnel, and their participation in EMAP field operations would be extremely beneficial. As key personnel directing field team activities year after year, they will provide the program with the continuity critical to EMAP field activities.

Logistics efforts among resource groups should be integrated as much as possible to reduce the cost. Shared regional logistics centers with permanent warehouse facilities and staff will aid in this integration.

The long-term success of EMAP is dependent on the development of an interagency program with common goals for monitoring the ecological condition of the environment. Wetlands monitoring alone could involve numerous agencies within the Department of Interior (e.g., USFWS, National Park Service), the Department of Agriculture (e.g., U.S. Forest Service), and the Department of Defense (ACO). As EMAP evolves into an interagency program, agreements between agencies will have to be established to define responsibilities. As with the EPA regions and states, these agencies have highly experienced field personnel, and it is anticipated that personnel from these agencies will participate in both field activities and the regional logistic centers.

The Boise Interagency Fire Center may serve as a model for EMAP future regional logistic centers. The Boise Interagency Fire Center is the national logistical support center responsible for coordinating and dispatching the closest suitable manpower, equipment, and aircraft for wildfires which exceed the capabilities of local and regional resources of land management agencies. This center is an interagency program with agreements between the U.S. Bureau of Land Management, the U.S. Bureau of Indian Affairs, the U.S. Forest Service, the National Park Service, the National Weather Service and the USFWS. The U.S. Bureau of Land Management manages the land and facilities, and is host to the other five agencies. The objectives of the Boise Interagency Fire Center are:

- Interagency programs and services developed through coordination and cooperation;
- Effective use of interagency programs and services by cooperating agencies; and
- Equitable cost sharing of interagency programs and services.

Similar arrangements need to be considered for interagency EMAP logistics centers.

7.5 TIMELINES FOR FIELD OPERATIONS

Arrangements for site access and field personnel will need to be made months in advance of field operations. Specific details regarding the location of sampling sites and the nature of field crews will be addressed in the Pilot Project Plan. The plan will outline the sampling schedule and will include information on wetland locations, sample dates, and all sample activities. The sampling schedule will take into account all activities that require time, including travel to the site, time at each sample station, and sample preparation. A field operations scenario will be included to demonstrate that the proposed field activities are logistically feasible within the allotted time frame.

7.6 PROJECT MANAGEMENT AND CONTINGENCIES

Any field program will be affected by unpredictable events (e.g., inclement weather, equipment failure) that can alter sampling plans. EMAP-Wetlands will define a management structure for responding to unanticipated events to ensure that the integrity of the 1991 Louisiana Pilot Project is not adversely affected when such events occur. In addition, a series of contingency plans for events that are likely to occur will be prepared in advance. These include, but are certainly not limited to, sample sites that no longer exist, inaccessibility to wetland or sampling stations, and unacceptable conditions for collecting data.

8.0 QUALITY ASSURANCE

It is EPA policy to ensure that the collection of data derived from environmentally-related measurements is of known and documented quality (Alvin L. Alm, U.S. EPA, pers. comm.). At the heart of the EMAP-Wetlands program will be the acquisition of enormous amounts of data collected by a variety of individuals and groups. Collected at great effort and cost, these data will become a national data base that will be used to assess the effectiveness of current regulatory policies in protecting wetland extent and condition. Because of the complexity and importance of this data collection effort, a quality assurance (QA) program must be developed that ensures that the type, amount, and quality of data that are collected are adequate to meet the study objectives.

Unlike regulatory and compliance QA programs which are required to implement an enforcement approach, the EMAP Wetlands QA program will be based on a philosophy of guidance, assistance, and commitment to improvement. Problems will be identified as soon as possible to minimize their impact on data quality. The appropriate training, technical support, and tools will be provided to all program participants to implement project QA that is consistent with the data quality requirements. While the emphasis of the QA program is to provide guidance and support, continuous poor performance that compromises data quality will not be accepted.

8.1 DATA QUALITY OBJECTIVES

Data quality objectives (DQOs) are statements of the level of uncertainty that decision makers who use the data are willing to accept in results derived from environmental data (U.S. Environmental Protection Agency 1989). Defining the level of data quality desired for a monitoring program is a critical, yet difficult task. While data must be of sufficient quality to satisfy project objectives, excess quality may provide little if any additional information and may be counterproductive when extra costs are involved (Taylor 1988). On the other hand, limitations on resources, time, methodology, and technical expertise are inevitable constraints that tend to limit the quality of data so that they have little value for problem solving. The DQOs development process provides a framework to balance the trade-offs between the project constraints and the quality of data needed to make sound decisions (Alvin L. Alm, U.S. EPA, pers. comm.).

The process of developing DQOs is an iterative one involving three multi-level stages that (1) define the decision to be made, (2) clarify the information needed for the decision, and (3) design the data collection program (Alvin L. Alm, U.S. EPA, pers. comm.). Fundamental to the DQOs process is the identification of potential sources of error. Two sources of potential error are sampling error and measurement error. Sampling error is the difference between the sampled value and the true value and is a function of natural spatial and temporal variability and sampling design. The temporal variability relevant to EMAP occurs within the sampling period. Measurement error is the difference between the true sample values and the reported values, and can occur during the act of sampling, data entry, data base manipulation, analysis, etc. Measurement error can be estimated for the parameters that will be used in EMAP-Wetlands. Data for estimating sampling error, on the other hand, are unavailable for many of the variables to be measured. Good estimates of temporal and spatial variability are essential to the DQO process because they are required to quantify the degree of uncertainty that will be produced by the sampling design. Because EMAP-Wetlands is the first program to estimate environmental parameters for wetlands on a regional scale and over an extended period, using standardized methods and a probability-based sampling design, acceptable estimates of variability are not available. For this reason, DQOs will not be implemented in the 1991 Pilot Project. Rather, one of the goals of the Pilot Project will be to gather relevant data to establish DQOs when the program is implemented on a regional scale.

Measurement quality objectives (MQOs) will be established for the 1991 Pilot Project. MQOs establish acceptable levels of uncertainty for each measurement process, but differ from DQOs in that they are not combined with sampling error to estimate programmatic uncertainty. MQOs are determined by obtaining estimates of achievable data quality based on manufacturer specifications, analytical methods, the judgement of knowledgeable experts and other available information. In subsequent years, DQOs will be developed to replace the MQOs.

8.2 QA REQUIREMENTS

There are five fundamental requirements that are necessary to meet the QA objectives. The approaches for evaluating and establishing the criteria to meet them are described below:

Accuracy and bias: Accuracy is the degree to which a measured value or property agrees with an accepted "true" value (Taylor 1988). Accuracy is estimated by measuring a sample with a known reference value. Bias is a systematic error inherent in a method or caused by some artifact or idiosyncrasy of the measurement system. One-way bias is estimated by interlaboratory comparison of performance evaluation samples among laboratories.

Precision: Precision is a measure of the scatter among independent repeated observations or measures of the same property made under prescribed conditions (Taylor 1988). Precision can be estimated at several points in the data collection process in order to estimate the effects of different sources of error. Precision can be partitioned into analytical and measurement system precision. Analytical precision refers to precision of the analysis performed by analytical laboratory instruments; it is estimated by laboratory replicates, including replicates of performance audit samples. Measurement system precision refers to the precision of the sampling process, including sample collection, storage, transport, preparation, and analysis. Collocated field duplicates are used to estimate precision of the entire measurement system, and laboratory splits are used to estimate the precision of sample processing after the sample has been received at the laboratory.

Completeness: Completeness is a measure of the amount of valid data actually obtained from a measurement process compared to the amount expected (Stanley and Verner 1985, Smith et al. 1988). The requirements for completeness will be determined individually for each indicator, or for each particular subpopulation of wetlands deemed of interest. In some cases, such requirements may not be easily determined *a priori*.

Representativeness: Representativeness is the degree to which data truly represent a characteristic of a population or environmental condition (Stanley and Verner 1985, Smith et al. 1988). Representativeness can be defined both qualitatively and quantitatively depending upon the sampling design and choice of sampling methods. To establish the desired degree of representativeness, the sampling design and subsequent use of the data must be considered. Representativeness can be affected by problems in any or all of the other indicators of data quality, the location of a sampling site, the time of sampling, the statistical selection of sampling sites, and the number of samples collected.

Comparability: Comparability is the degree of confidence with which two or more data sets may be compared. Comparability of data sets generated within EMAP-Wetlands is an important characteristic of data quality, because monitoring activities will be carried out at different locations and by different personnel and possibly over long time periods. Comparability of data from EMAP-Wetlands to similar data from other projects is also of interest, namely, other EMAP resource groups (e.g., Surface Waters and Agroecosystems), other monitoring efforts that may be developed in the future, and other existing programs (e.g., the EPA Wetland Mitigation Program which is developing and testing techniques to assess the effectiveness of wetland restoration and creation efforts).

Comparability can be evaluated within a single sampling period, over a complete sampling cycle (4 years), and among sampling cycles. Comparability can be maximized through the use of standardized methodologies, documentation of modification or changes in methods, and carefully designed methods comparison studies. It can be evaluated quantitatively using estimates of precision and bias. Comparability studies between old and new methods will be essential for trend evaluation.

8.3 QUALITY ASSURANCE/QUALITY CONTROL PROGRAM

Quality Assurance is defined as an integrated set of activities including the plans, specifications, and policies affecting the collection, processing, and reporting of data. It is the system of activities designed to provide management with independent assurance that total system quality control is being effectively implemented (Taylor 1988). A QA program involves **quality control** (QC) procedures which reduce and maintain random and systematic errors within tolerable limits (Taylor 1988) and **quality assessment** procedures which evaluate the effectiveness of the quality control procedures and evaluate the quality of data produced. Procedures associated with QC provide immediate feedback so that corrective action can be adopted by field and laboratory personnel without delay. The quality assessment program is implemented to monitor sources of error so that control measures can be optimally allocated among points in the process where they are most needed. Each stage in Figure 8-1 represents a point at which QA/QC measures can be implemented.

8.3.1 QA Guidelines

Primary guidance for implementing the QA program will be provided by the EMAP Quality Assurance Program Plan [U.S. Environmental Protection Agency, in press(b)]. QA guidelines that provide management oversight to maximize the success of a QC program are described below and include (1) documentation of procedures related to design, sampling, measurement, information management, data analysis, reporting, and QA; (2) standard operating procedures; (3) standardized training programs to ensure a minimal level of competency; (4) selection of appropriate facilities and equipment; and (5) periodic site visits by knowledgeable members of the QA staff.

8.3.1.1 Documentation

Prior to the implementation of field sampling operations, a number of QA related documents will be prepared (or existing documents will be modified to reflect program improvements). These documents are described below.

- EMAP Quality Assurance Program Plan (QAPP): Describes the philosophy and QA policies of EMAP and provides the primary guidance for designing and implementing QA programs within EMAP.

- Wetlands Quality Assurance Project Plan (QAPjP): Details the specific QC and quality assessment activities that will be used in the QA program for EMAP-Wetlands. Outlines the policies (e.g., system for reporting to management), organization, objectives, and functional activities (e.g., sampling procedures) that pertain specifically to the QA program for EMAP-Wetlands. This document will be used as guidance in preparing QAPjPs for special studies, be they regional or local in focus. The QAPjP will be reviewed and approved by the EMAP QA coordinator, the Wetlands Technical Director and the Wetland QA officer.

- Field Operations Manual: Details standardized operating procedures for sample collection, handling, and processing, collection of field data, and data management activities (including QA and QC

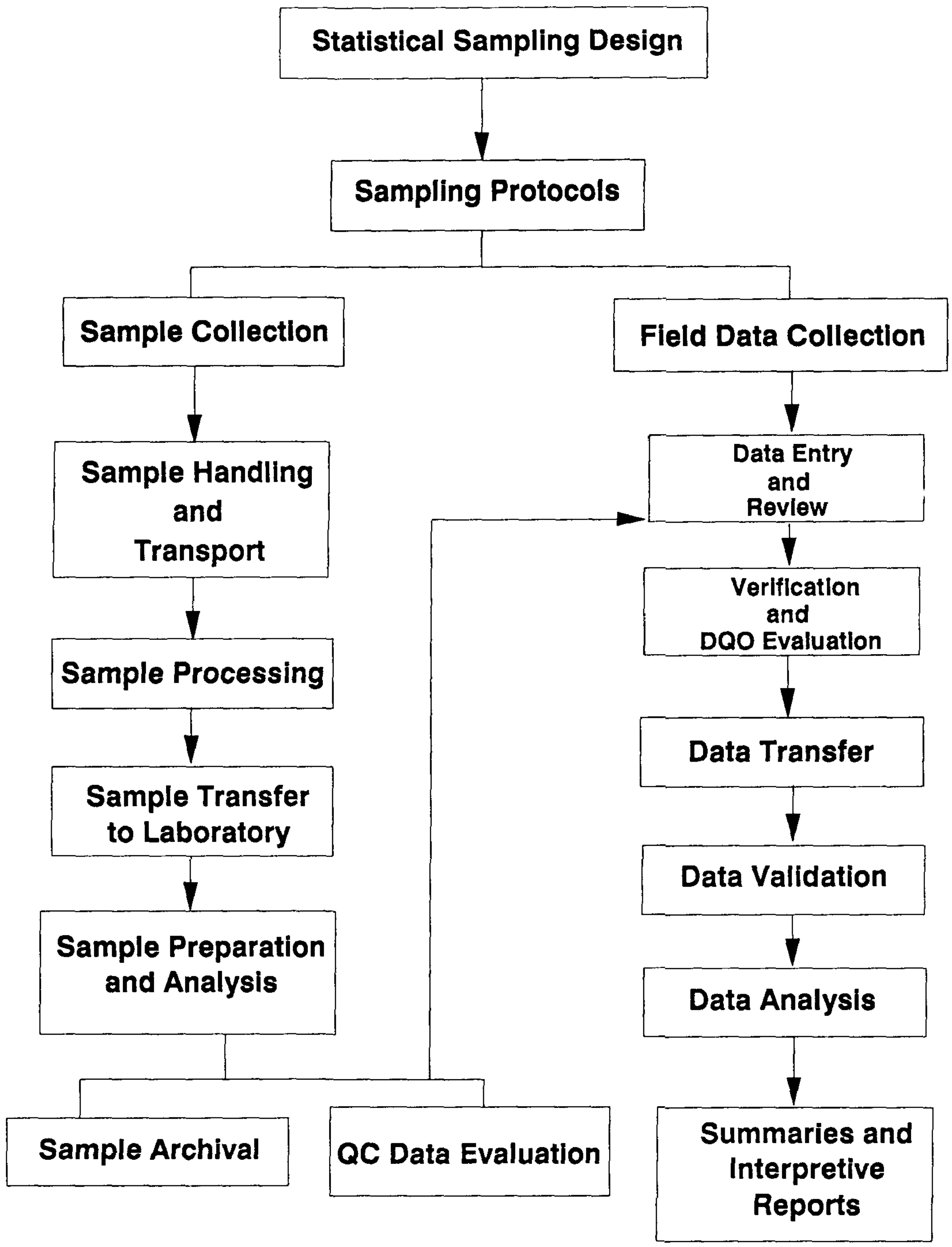

Figure 8-1. Flow of data acquisition and management activities for EMAP-Wetlands and points to where data quality can be controlled or assessed.

procedures). Also describes other logistical procedures (e.g., sample shipping, waste disposal, communications, safety) conducted in the field (see Section 7).

- o Laboratory Operations Manual: Details standard operating procedures for sample analysis, including QA/QC procedures. Also explains quality assessment methods for the QC data collected including the construction of control charts and variables to be charted.

- o Technical Coordination QAPjPs: Details the QC and quality assessment activities that will be used by the Landscape Characterization and Information Management support groups.

- o QAPPs and QAPjPs for other participating groups (including agencies, laboratories, and principal investigators) that may be appropriate in specific circumstances. These plans will meet or exceed the requirements set forth in the EMAP QAPP and the Wetlands QAPjP.

QA documentation pertaining to EMAP-Wetlands will be reviewed periodically and revised as necessary to reflect changes based on previous performance, or other modifications to either the QA program or to EMAP in general. Changes in various aspects of the QA program will also be incorporated into revision of standard operating procedures related to sample collection and measurement. Documentation of methods and methods modification over time will be essential to evaluate trends in wetland condition.

8.3.1.2 Standard Operating Procedures

A standard operating procedure (SOP) is "a written document which details an operation, analysis, or action whose mechanisms are thoroughly prescribed and which is commonly accepted as the method for performing certain routine or repetitive tasks" (Environmental Protection Agency 1989). Standard operating procedures will be developed for all sampling activities to meet the QA requirements described above. Because standard sampling procedures do not exist for many of the proposed indicators, an essential component of the pilot studies will be to field test methods for standardization.

For each major measurement parameter, a description of the sampling procedure to be used will be documented. Documentation will include, where applicable:

- o Description of techniques or guidelines used to select sampling sites.

- o Inclusion of specific sampling procedures to be used (by reference in the case of standard procedures and by actual description of the entire procedure in the case of nonstandard procedures).

- o Charts, flow diagrams or table delineating sampling program operations.

- o A description of containers, procedures, reagents, etc..., used for sample collection, preservation, transport, and storage.

- o Special conditions for the preparation of sampling equipment and containers to avoid sample contamination (e.g., containers for organics should be solvently-rinsed; containers for trace metals should be acid-rinsed).

- o Sample preservation methods and holding times.

- o Time considerations for shipping samples promptly to the laboratory.

- o Sample considerations for shipping samples promptly to the laboratory.

- Sample custody or chain-of-custody procedures.

- Forms, notebook, and procedures to be used to record sample history, sampling conditions and analyses to be performed.

Relevant SOPs will be documented in either Laboratory Operations Manuals or Field Operations Manuals and QAPjP's. The EMAP-Wetlands Quality Assurance Officer will have primary responsibility for approval of SOPs.

8.3.1.3 Training Programs

Qualified personnel responsible for collecting field data and samples will be trained by experts to conduct the assigned tasks using the specified methods and to provide consistency for all sampling activities. Because laboratory processing and analysis will be conducted only at laboratories having ongoing QA programs using standard protocols and personnel training, laboratory personnel involved in the program will not require training. However, select lab staff will be requested to participate in field training to address relevant laboratory concerns related to field sampling activities. Training sessions will be conducted for the team leader, crew chiefs, and the crew members. At the end of the training sessions, all crew members will be required to demonstrate proficiency in the following:

- Operation and trouble shooting of analytical field equipment;

- Sampling methodology and site procedures;

- Entering data into and retrieving data from a portable data logger; and

- Safety issues including the administration of first aid and CPR.

Proficiency will be evaluated by participation in mock sampling activities and (or) a written examination and the results of the exams will be documented. Individuals who do not demonstrate a desired level of proficiency (determined *a priori*) will be required to undergo retraining. Individuals who cannot demonstrate proficiency after retraining will not be allowed to participate in the sampling activities.

Some sampling activities will require specialized knowledge (e.g., plant taxonomy). When individuals are not experienced or trained in the areas requiring specialized knowledge, then intensive training will be provided to selected crew members. At the conclusion of the training program, at least two members of each crew will have demonstrated proficiency in each of the tasks requiring specialized knowledge, and the crew leaders will be familiar with all sampling protocols.

Each sampling team will be receive copies of the Methods Manual which will detail all phases of field operations. The manual will include a checklist of all equipment, instructions on the use of all equipment, preventative and routine maintenance, and procedures for sample collection. In addition, the manual will include a schedule of activities to be conducted at each sampling location. It will also contain a list of potential hazards associated with sample sites and sampling procedures.

8.3.1.4 Facilities and Equipment

Suitable facilities and equipment are an essential component of a successful QA program. Performance evaluation criteria will be developed and performance evaluation samples analyzed to assess the competence of potential laboratories. Only those laboratories with modern facilities who have a competent and experienced technical staff, that have demonstrated good laboratory and remeasurement practices will be selected.

8.3.1.5 Site Visits

Periodically, field sites will be visited by trained members of the QA staff to ensure that sampling and measurement activities are being conducted appropriately. These visits also provide timely guidance to address questions and recommend corrective actions. In addition, the visit ensures that the procedures and equipment are appropriately maintained and that personnel and laboratory facilities are capable of continued operations. QA personnel will develop checklists to serve as guidelines during the site visit. A site-visit report will be submitted to the Technical Director and the EPA QA Coordinator that evaluates the team performance and suggests corrective action.

8.3.2 Quality Control Guidelines

Quality control provides specific information on the level of confidence that can be assigned to each data point. Some components of QC are the (1) implementation of a standardized program of calibration and preventative maintenance for all sampling and analytical equipment and instrumentation,
(2) implementation of standardized methodology, (3) proper documentation of all operations, and
(4) implementation of QC checks throughout the sample collection and analysis programs.

Quality control checks validate both the collection and measurement processes using samples of known composition, through replicate measurements, and through maintenance of control charts. These tools allow for rapid identification and resolution of problems related to sample collection or measurement, and provide documentation that the process in being maintained in a state of statistical control. The frequency of QC checks will be based on the nature of the indicator and measurement method, the significance of the data, and the risk of error. A list of general QC check samples and their targeted error is presented in Table 8-1. It is important to recognize that the utility of QC procedures will be constrained by the brief index period each year (approximately 4 weeks) and by the turnaround time between collection of samples and subsequent analysis. Revisiting sites because of post *priori* identification of a problem will not be feasible in most cases (although sample reanalysis will be, depending on the amount of sample remaining and the holding time requirements). It thus becomes critical to minimize the potential for sampling-related errors through careful attention to QC procedures.

8.3.2.1 Chemical Measurements

The use of QC checks for chemical measurements are well documented (e.g., Hunt and Wilson 1986, Taylor 1988). Specialized collection and handling procedures may be required for certain types of samples. Water samples, for example, may require special bottles and preservatives to minimize contamination and prevent changes in composition between collection and analysis. Field blank samples will be used to monitor possible contamination during collection and analysis of water samples.

Appropriate types of control samples and control charts will be used in the laboratory to monitor and evaluate statistical control of the analytical process. For inorganic sample analyses, at least one check standard (at a concentration near the middle of the calibration range) will be analyzed periodically with the routine samples. Additional standards may be necessary to determine detection limits for analytes present in low concentrations. For organic analyses, internal standards may not be available; duplicate analyses on a subset of routine samples will be required to monitor random and systematic errors.

Table 8-1. Quality Control Checks That Will Be Used in the EMAP-Wetlands QA Program.

QC Check Purpose	Collection Point	QC Sample Type
Estimate precision of measurement system	collection	field duplicates
Estimate precision of sampling process	sample preparation	laboratory splits
Estimate precision of analytical system	analysis	analytical replicates
Detect contamination from sample processing	collection	field blanks
Check instrument performance; estimate analytical precision and accuracy	analysis	QC check samples
Estimate analytical detection limit	analysis	low-level QC check samples

8.3.2.2 Biological Measurements

Representativeness of biological measurements will be largely determined by the sampling design. Control criteria will be established when possible to ensure an adequate sampling effort has been conducted to collect representative biological samples. In cases where this is not feasible, additional measurements will be collected at a subset of sites to provide an estimate of sampling precision. The estimates can subsequently be used to develop control criteria as the program continues. Repeated or independent checks in sample processing and taxonomic identifications will be conducted on a subset of samples. Comparability among field technicians will be evaluated when appropriate (e.g., estimates of percent vegetation cover). Voucher collections of biological specimens will be developed and maintained by participating groups during the course of the program. These collections will be archived at a permanent collection facility (e.g., university) for future reference.

8.3.2.3 Habitat Quality and Site Characterization Measurements

Quality control activities associated with the landscape characterization measurements being conducted in support of EMAP-Wetlands will be documented in a separate QAPjP. For those measurements being collected as part of the EMAP-Wetlands effort, the most critical QC activities (once standardized methods are implemented) are the development and use of standardized codes and categories. For measurements collected from maps, an independent check of the measurements conducted periodically by a second person (or group) would serve to detect and correct errors on a timely basis. For data being collected during site visits, proper calibration of instruments and repeated measurements by a second person on a subset of sites would be used as the primary means of minimizing errors. Such repeated measurements also provide estimates of the magnitude of measurement errors. It would be desirable to implement methods to monitor for systematic errors in collecting these data (whether they result from a particular method or from different crews that utilize a method).

8.3.2.4 Archival of Samples and Specimens

Archival activities will involve samples for chemical analyses and the curation of biological specimens. For chemical samples, samples of water and sediment will generally be archived for a particular period, in case some type of reanalysis is warranted. Some types of samples (or subset) may be preserved and archived for longer periods to permit future analyses of constituents other than those initially determined. An example might include more detailed analyses of samples when the results of bioassay experiments indicate possible toxicity. Such long-term storage may be feasible for some inorganic constituents, but may not be feasible for organic compounds.

Voucher specimens of plants and possibly invertebrates will be collected as part of the routine QC program. Periodically, such specimens will be placed into a permanent collection. Possible options for curation include the establishment of a specimens banking and curation system specifically for EMAP, or to make arrangements with regional facilities (e.g., national museums, university herbariums, or state biological survey agencies) to incorporate specimens collected as part of EMAP into permanent collections. The archival of specimens would be reported in the appropriate summary or interpretive reports.

8.3.3 Quality Assessment

Data quality will be assessed within a region, within a sampling cycle, among regions, and among sampling cycles. Data quality will be evaluated qualitatively and quantitatively. Qualitative assessment will include the periodic evaluation and revision of documents and site visits to the field and laboratory to ensure consistency among participating groups and adequate performance. Quantitative assessment will attempt to estimate errors that are important in interpreting indicators and in identifying the need for QA program improvement (i.e., to adjust the effort and intensity of QC to areas where it is needed the most). These errors will be estimated through performance evaluation studies. Assessment results will be included in final reports.

Performance evaluation studies will be carefully designed to assess errors associated with performance. These studies will test null hypotheses related to data quality requirements for random and systematic errors. The design will be based on consideration of Type I and Type II errors, and will attempt to provide estimates of (1) the overall variance that can be used in data interpretation and (2) important components of the variance within the measurement error that can be used to determine which steps in the collection and measurements process require more or less QC emphasis. The sample sizes and frequency of measurements will be optimized to provide the necessary answers in the required reporting period.

Performance evaluation studies could be conducted using (1) performance audit samples for chemical analyses, (2) reference samples for biological measurements, and (3) natural samples (either biological or chemical) for interlaboratory comparison (round-robin) studies. Depending on the constituent, materials for performance evaluation studies may be limited in their availability and appropriateness (e.g., sediment chemistry and plant tissue).

Using different methods or modifying methods over time may influence data interpretation, particularly the detection of trends in ecological condition. Standard guidelines for implementing a new methodology in a region or at a specific site will be provided. Performance evaluation studies will provide some information on methods comparability, but comparability studies should be a more intensive effort designed to test specific hypotheses related to the comparability with previous methodology. Such a comparability study must be conducted, evaluated, and approved before new or modified methods can be implemented.

8.4 DATA MANAGEMENT

Components of information management that ensure that data are complete and accurate include data entry, review, verification, and validation. Other components of information management are presented in Chapter 9. Data entry and review procedures will be automated to the extent possible. This approach minimizes errors associated with sample and measurement collection by allowing information to be reviewed as soon as possible after these activities are done. Data will be captured electronically when feasible using standard data collection forms as backups. Portable field computers having data screens that emulate manual field forms are currently being tested by other EMAP resource groups with success. Electronic data capture reduces the expense and time required for data entry and can facilitate and enhance data verification. The data entry programs and field forms will be carefully designed for accurate, efficient data collection. They will be field tested and modified as necessary before data collection activities begin. An explanation of the variables and all pertinent data collection information (i.e., explanation of all data entry fields and terminology) will be prepared and made available to the field crews.

Errors associated with the omission of important information relating to a legitimate data value will be minimized using data qualifiers (Kanciruk et al. 1986). Data qualifiers assist in the correct interpretation of data values. Data qualifier flags will be assigned based on the nature of the information. For example, protocol flags will be assigned when data were gathered without following the proper protocols (e.g., shortage of sample preservative). Default flags will be assigned based on known data (e.g., sensor calibration). Qualifying information will be anticipated and a structured system for recording and retrieval of this information will be developed. The system will be designed with flexibility to allow the inclusion of unanticipated qualifiers.

Data will be reviewed before and after data entry for completeness and, when possible, accuracy. Field data will be reviewed prior to leaving each site by the crew leader. Data from QC samples or measurements and control charts will be evaluated to determine if reanalysis or remeasurement is required before data are entered. Immediately after data are entered, they will be compared to the raw data. All mismatches will be flagged during the second entry, and obvious errors will be corrected. If there is any disagreement about the proper identity of the datum in question, the data field will be flagged as missing information; all original data will be maintained in the information management archival system.

Data verification is a process which evaluates data for accuracy and, when appropriate, consistency. Data will be automatically evaluated during data entry using range checks (e.g., pH entered as 701 instead of 7.1), entry duplication checks, proper format checks, and frequency checks to identify inappropriate codes. Examples of consistency checks include ion balance and conductivity calculations for inorganic chemical constituents; for biological samples, consistency checks might include checks for missing taxa and taxonomic accuracy of species identifications.

Whereas data verification is an internal data review process, validation examines data holistically by comparing data against regional expectations. The purpose of data validation is to identify and explain outlier samples or sites. Data validation will be done by a statistician in collaboration with other appropriate people who have knowledge of the data (e.g., field and laboratory personnel). The process involves association and multivariate analyses; the utility of using existing dynamic simulation models to assist in this process is also being considered. Identified outliers will be evaluated using data qualifiers and historical data, and decisions will be made to either correct obvious errors, omit them from the analysis or include them in the analysis. Data will be changed only when the correction is obvious. Data which are changed or omitted will be flagged appropriately. All data discrepancies that are identified will be documented and archived.

8.5 OTHER QA CONSIDERATIONS

Although the large-scale synoptic monitoring program will comprise the major effort of data collection, additional studies will be conducted that may require project-specific QA programs. Special studies may include investigations of possible cause and effect relationships between ecological components or processes and changes in ecosystem condition. Each of the levels of implementation (e.g., pilot study, regional demonstration) will also require a QA program of differing levels of focus or intensity, yet the QA programs must ultimately be compatible with each other, and with the overall approach to QA taken by EMAP as a whole.

Participation by an array of diverse organizations is expected, and over the long lifetime of the program, the list of participants will undoubtedly change. These groups have different levels of expertise in the principles and practices of QA. Existing monitoring programs considered for integration into the EMAP framework may have QA requirements that are initially incompatible with those established for EMAP-Wetlands, or EMAP as a whole. Differences in sampling and analytical methodology, whether among participating groups, among regions, or as a result of new technologies over the life of EMAP-Wetlands, must be monitored and assessed in order to quantify and minimize their impacts on the interpretation of the observed status and trends in ecological condition.

8.6 ORGANIZATION AND STAFFING

Authority for implementing the QA program for EMAP follows the organizational hierarchical line outlined in the EMAP QAPP [Environmental Protection Agency, in press (b)]. The EMAP Quality Assurance Coordinator (QAC) is charged with the responsibility for administering the EMAP-QA Program and oversight activities. Some examples of the specific responsibilities of the QAC include the following functions: Preparing the draft EMAP QAPP and subsequent revisions; facilitating DQO development; assisting EMAP Technical Directors in interpreting, understanding, and implementing the QAPP; and coordinating methods selection and development across resource groups. The documents requiring QAC approval include the EMAP QAPP and the EMAP-Wetlands QAPjP.

The design and implementation of the overall QA program for the Wetlands component of EMAP is the responsibility of the Wetlands QA Officer (QAO). The EMAP-Wetlands QAO serves as the QA advisor to the Technical Director (TD) and assists the TD in administering the QA program. The QAO is responsible for interpreting Agency QA policy and developing, in cooperation with line management, the QA policies of their organizational elements. The QAO assures that these policies adequately reflect their organizational program QA needs and that they are consistent with and carry out the intent of the EMAP QAPP and the Agency's mandatory QA program. The QAO approves the EMAP-Wetlands QAPjP and the SOPs.

When fully implemented, the QAO will be assisted by several coordinators to implement the QA program. Special projects on regional scales will have a designated Wetlands QA coordinator to oversee the QA program for the project. It is anticipated that each localized, intensive monitoring program will have a designated on-site QA representative, who will be supported by the QAO and the EMAP-Wetlands QA Coordinator.

8.7 QUALITY ASSURANCE DOCUMENTATION AND REPORTING

In addition to the documentation described in Section 8.3.1.1, other types of reports will be produced periodically as part of the QA program. These include: (1) summary reports of site visits, (2) performance evaluation (or method comparison) summaries, and (3) assessments of data quality. Summary reports of site visits will serve to identify and track issues and subsequent corrective actions, and provide information to update other QA documentation. The results of performance evaluation studies will be reviewed and returned to participants within a short time after submission. Evaluation summaries of QA-related data and other appropriate information will be prepared and included in the appropriate EMAP-Wetlands reports.

In addition, QA monthly reports and a QA Annual Report and Workplan (QAARW) will be completed [U.S. Environmental Protection Agency, in press (b)]. The QA monthly report summarizes major accomplishments of the Wetlands QA program in the previous month as well as problems encountered, remedial actions taken and the results. The QAARW will track annual QA activities and accomplishments (e.g., projects/organizations that were audited/reviewed, major SOPs that were developed, and changes to existing QAPjPs) and will outline plans and resources for the next fiscal year.

QA documentation will be reviewed annually and revised as necessary to reflect changes in standard operating procedures, changes based on previous performance, or other modifications to either the QA program or to EMAP in general. Changes in sample collection and measurement procedures should also be incorporated into revision of standard operating procedures related to sample collection and measurement.

Performance evaluation data must be analyzed and summarized by all participants and submitted to the appropriate QA Coordinator for review within the required time. Evaluation summaries of QA-related data will be prepared and included in the appropriate EMAP-Wetlands reports.

9.0 INFORMATION MANAGEMENT

Due to the nature and complexity of the data that will be collected for EMAP-Wetlands, a highly efficient, computerized management system will have to be developed. This information management system must be available, at various levels, to other EMAP resource groups, other local, state, and federal organizations, and to academic institutions. Each kind of user requires timely access to data that has been summarized to varying degrees and in specific ways. To meet their needs, many different kinds of analyses will be conducted ranging from tabular summaries and statistical comparisons to evaluation of spatial distributions using Geographical Information Systems (GIS). The system must also have the capability to draw from historical data bases already in place for similar environmental monitoring efforts, and be compatible across all EMAP resource group information management systems.

9.1 ROLE OF INFORMATION MANAGEMENT

Each resource group is required to develop an Information Management Program prior to implementation of field activities. This program will support and facilitate all aspects of EMAP-Wetlands, including project management and planning, data collection, logistics, sample preparation, tracking, and collection methods, data quality parameters, and communications. The Information Management task group will interact with the project manager, logistics coordinator, and QA/QC personnel to determine their requirements and taylor the capabilities of the Information Management Program to suit their needs.

The objectives of the EMAP-Wetlands Information Management Program are as follows:

- Design an information management system to meet user requirements from within and outside of EMAP.
- Provide state-of-the-art information management technology within the guidelines of the Office of Information and Resource Management and the confines of available resources.
- Facilitate the wide use of EMAP-Wetlands data.
- Ensure integration among users.
- Develop a flexible information management system that can adapt to the changing needs of the program.
- Provide timely distribution of data.

9.2 USER REQUIREMENTS

9.2.1 Levels of Data

Data will be disseminated to users in the categories listed below:

- Raw data -- unmodified data collected in the field or analytical laboratory;
- Verified data -- raw data files that have been reviewed for completeness and accuracy;
- Validated data -- verified data files that have undergone validation analyses;

- o Enhanced data -- validated data files that have missing values filled in using established procedures; and

- o Summarized data -- data that have been analyzed and summarized for presenting in reports.

9.2.2 Users

The users of EMAP-Wetlands data can be separated into five categories based on the level of data processing required to meet their needs:

1. The EMAP-Wetlands resource group, which will be comprised of individuals and groups involved with daily field operations and tasked with the design, implementation (e.g., logistics and QA/QC personnel), and some interpretation of data from the field sampling programs.

   This group will require access to a comprehensive data set, on a real time basis, including:

   - o project management information,
   - o raw data files,
   - o project management information,
   - o sample tracking,
   - o QA/QC reports,
   - o field logs,
   - o logistics,
   - o summary reports,
   - o maps,
   - o verified and validated data sets, and
   - o applicable historical data sets.

   This group will work primarily with raw data, that has not been quality assured, but will also require access to all data described below.

2. The EMAP-Wetlands Management Team, which will include individuals and organizations primarily involved in the overall program, but not necessarily involved with daily field operations. This category includes participating groups, GIS support personnel, QA/QC personnel, program reviewers, and EPA Headquarters personnel.

   This group will require access to summary information related to project management and logistics. They will require access to files that have been validated and verified. They do not require real time access, nor do they need to have access to a comprehensive data set.

3. The EMAP Program Management, which will include all individuals and cooperating organizations directly involved in design, implementation, and analyses for the overall program. These individuals include members of other resource groups, members of the Integration and Assessment task group, and personnel in other agencies directly involved in EMAP.

   This group will require final summaries related to project management and logistics. They may require access to some validated and verified data files. They do not require real time access, nor do they need to have access to a comprehensive data set. They need data in a context which can be integrated with data from other disciplines. Document summaries with interpretation and graphic outputs will be most useful.

4. Other local, state, and federal agencies involved in similar environmental monitoring programs, including the EPA Regions, other EPA offices, state environmental agencies, academic institutions, and the scientific research community.

   This group will require access to validated and verified data sets. They will need summarized characterization data for each station sampled. They will also require access to an index of available data, both EMAP and historical data. Documented summaries with interpretation and graphic displays will be most useful to this user group.

5. Legislators, environmental managers, and the general public will require access to summarized, interpreted data through published reports.

9.2.3 User Issues

9.2.3.1 Data Integrity and Security

Database security is essential to ensure the integrity of the data. All data will be made available in "read only" format, allowing users to access the data for numerous tasks (e.g., analysis, plotting, and transfer to other computers) without compromising the integrity of the data base. Access will be limited where the quality of the data are suspect. Other measures that will be taken to maintain data integrity include protection against mismanagement, viruses, unauthorized access, and hardware/software failure.

9.2.3.2 Data Confidentiality

Other agencies have data bases that we may need to access and agreements may be necessary, depending on the agency, that ensure data confidentiality and controlled access. The USFWS, for example, provides maps of wetland locations to the public, but does not reveal the locations of monitoring sites. EMAP, EPA, and inter-agency policies on data confidentiality are currently being addressed (Franson 1990).

9.3 FUNCTIONAL REQUIREMENTS AND SYSTEMS MANAGEMENT

9.3.1 Functional Requirements

EMAP-Wetlands has three functional levels of operation: resource group projects, resource group program, and EMAP program overall. In order to support the needs of these levels, EMAP-Wetlands must provide the following products and services:

1. Resource Group Projects

o field data collection (e.g., data loggers, bar code readers)
o sample tracking
o analytical laboratory data collection
o QA/QC analysis and reporting
o data transfer from other agencies
o configuration management

2. Resource Group Program

o access to existing data bases
o data integration and analysis
o data base management
o presentations and reports

3. Overall EMAP

- o data base transfer/access
- o data base cataloging
- o archival/back-up of data
- o integration of data from multiple resource groups
- o training and support

At each level, programs will be designed, developed, and tested to meet the required needs. Standardization of components will facilitate QA activities. Resource group standards will be developed by the EMAP Information Center (EIC) with input and review from the Information Management Committee (IMC).

9.3.2 Systems Management

In order to respond to the user and functional requirements, a central information processing center will be *established for* EMAP-*Wetlands at the* Environmental Research Laboratory - Corvallis (ERL-C). The Wetlands Information Center (WLIC) will be the focal point for planning, coordinating, and implementing the information management program for the wetlands component of EMAP. The WLIC is composed of personnel and hardware/software resources that support the EMAP-Wetlands Information Management Program. The responsibilities of the WLIC include:

- o Designing and implementing a data system which will meet the needs of the users of EMAP-wetlands data;
- o Interfacing the EMAP-Wetlands data management effort with the EMAP central information management effort;
- o Establishing data management standards and procedures for EMAP-Wetlands;
- o Maintaining a comprehensive EMAP-Wetlands data inventory, data dictionary, and sample tracing system;
- o Maintaining and disseminating summary data;
- o Supporting data processing needs of the remote nodes/field crews; and
- o Establishing liaisons with appropriate data management personnel in other agencies to arrange for cooperative information exchange.

When EMAP-Wetlands is fully implemented, the WLIC will be supported by a full time professional staff. The staff and their responsibilities are provided below.

Wetlands Information Manager: Senior Information Management staff that directs the WLIC and is responsible for planning, coordinating, and facilitating information management activities. The Information Manager reports to the Wetlands Technical Director, and is responsible for ensuring that data and information collected are properly captured, stored, and transmitted. As an executive member of the IMC, the Information Manager serves as liaison between EMAP-Wetlands and the Information Management Director, representing the needs of the wetlands resource group.

Data Base Administrator: Responsible for assembling, documenting, and administering the EMAP-Wetlands data bases.

Programmer: Responsible for development of programs to manage data collection, tracking, and dissemination to include data entry screen design, reports, sample tracking, and analysis.

Data Clerk/Librarian: Responsible for documenting EMAP data sets and assisting in the development of the EMAP-Wetlands Data Catalogue and Data Dictionaries.

Technical Support: Responsible for the installation and maintenance of all hardware, software, and communications.

The EMAP Information Management Program support structure includes the following staff:

EMAP Information Management Director: Responsible for the development, implementation, and administration of the overall EMAP Information Management Program.

EMAP Information Management Committee: A coordination and advisory committee responsible for providing insight, recommendations, and guidance to the Information Management Director on the program's information management requirements and activities.

EPA Office of Information Resource Management (OIRM): EMAP will work with OIRM to assure that the EMAP Information Management Program is properly planned and coordinated with the Agency's Program and the EMAP's resource requirements are conveyed through the appropriate channels.

9.4 OPERATIONAL REQUIREMENTS

9.4.1 Information Management System

The Wetlands Information Management System (IMS) must have the flexibility to process an array of data types resulting from sampling activities. For the 1991 Pilot Project, the Statistical Analysis System (SAS) will be used as the data management system. Although SAS is an industry standard statistical package capable of performing both simple and complex data analyses and modeling, it does not have the flexibility of relational data base management systems to efficiently manage and access complex data sets. Currently, no relational data base system is available to the EPA through current contracting mechanisms. When a relational data management system is made available to the EPA through the Office of Information Resources Management, the EMAP-Wetlands IMS will be converted to the selected relational data base system. SAS will continue to be used as a principal data analysis tool.

The EMAP-Wetlands IMS will consist of the following operational components: project management, data collection, processing and storage of indicator data, data access and transfer, data analysis and reporting, and data documentation. The flow of data through the Wetlands IMS is presented in Figure 9-1.

9.4.2 Project Management

Project management personnel will require frequent and accurate status reports about field collection and laboratory processing activities. The project management component of the IMS will be designed to meet these needs. There are two major elements of a project management IMS: (1) a communications system for rapidly transferring information between field crews, processing laboratory, and the EMAP-WLIC; and

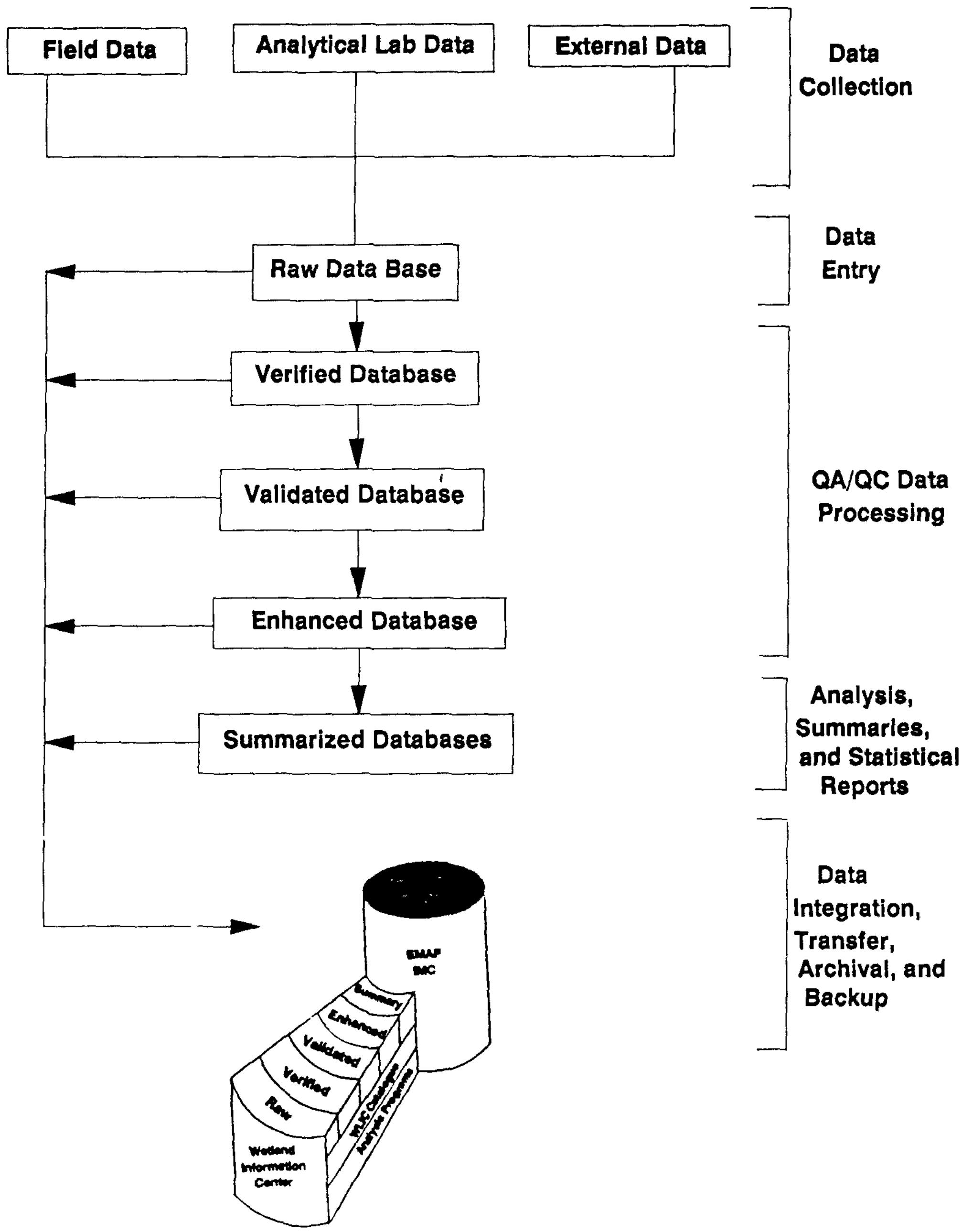

Figure 9-1. Flow of data and associated activites for the EMAP-Wetlands Information Center.

(2) a sample tracking system for monitoring the status of sampling events, sample shipments, and status of analyses on a real time basis.

9.4.2.1 Communications

A communications system will be designed to facilitate the exchange of information among field crews, processing laboratories, and project management. The system will allow field coordinators to transfer instructions, changes, and queries to field crews; it will track the transfer of samples from the collection to the processing laboratories; and it will facilitate the transfer of data from field computers to the central data processing center. For example, programs will be developed that will automatically log remote computers into the central processing center and to perform file transfers into predetermined directories. Initial processing of the data will be initiated automatically, When processing is complete, the WLIC will be notified and requested to acknowledge that data have been received and are ready for additional processing.

Field crews will have access to logistical data through the WLIC communications link. These data will include information about support services (e.g., supplies, overnight delivery, motels), sampling locations (e.g., latitude and longitude coordinates), and protocols (e.g., sample identification numbers, variable-field explanations).

9.4.2.2 Sample Tracking

The sample tracking system will track samples from initial collection through completion of all analyses and (or) processing. To accomplish this, each sampling event and sample type will be assigned a unique identification number. These numbers will be entered into the IMS prior to collection of data. Sample numbers will be identified by bar codes to facilitate data entry by the field crews. Information entered for each sample in the sample tracking system and available for retrieval and review include:

- Sample site information (eg., latitude and longitude);
- Time the sample was collected including date, hour, and duration of sampling effort;
- Type of sample (e.g., grab samples to be processed for benthic species composition, sediment samples to be processed for contaminant concentrations);
- Identification of the individual/team that collected the sample;
- List of the analyses and processing activities planned for that sample, and the status of those analyses and activities (e.g., collection completed, analyses completed);
- Directions to files containing raw data generated for each sample; and
- Directions to textual files containing descriptive information about the sampling event (e.g., field team comments).

When samples are transferred from field crews to analytical laboratories, a record of the exchange will be entered into the sample tracking system, both upon release and upon receipt of the material. The identity and disposition of any sample can then be established by checking the sample status in the IMS. The status of all analyses and results will be available through the sample tracking system. When all processing for a sample is complete, a "flag" will be set, and someone will be automatically notified when logging onto the VAX computer. The GIS system will be linked to the sample tracking system to display the status of sampling activities.

9.4.3 Data Collection

Field data will be entered directly into a portable field data recorder. These data include direct field measurements (e.g., water conductivity) as well as site information (e.g., site identification number, latitude/longitude). The data will be automatically verified as described in Section 9.5. Field data will be submitted to the centralized system in established time frames and in approved formats.

9.4.4 Processing and Storage of Data

All data received by the WLIC will be converted into SAS data sets. The data sets will be stored in data libraries by indicator type. Following initial data processing, the required data analysis will be performed and summary data bases produced. The IMS will maintain data and relevant analytical results in both raw and summarized forms. This will eliminate costly and redundant analyses.

9.4.5 Data Access and Transfer

Data will be accessible through the EPA VAX network. All documentation of data base design, including the code libraries, data dictionary, standard operating procedures for data handling, and GIS standards and base coverages will be available over this network. Users who do not have access to the VAX network will be provided direct dial access to the WLIC, as appropriate. Ultimately, the data will be made available to the users. Access authorization will be established under the direction of the EMAP-Wetlands Technical Director. Access to data which are deemed confidential or suspect will be limited.

All data made available for general use will be in read-only format, allowing users to access the data without compromising their integrity. Requests to obtain copies of or access to data in the IMS will be submitted to the qualified person. A schedule will be developed for providing access to these data. The release schedule will depend on the availability of personnel to process the data, as well as the urgency of the request.

9.4.6 Data Analysis and Reporting

Analysis will be done only on summarized data that have passed QA evaluation. Programs developed for the analysis will be designed by qualified scientists. Data exchange interfaces will be developed between the data management system, GIS, and other tools for data analysis.

An important requirement of the WLIC is the ability to generate maps and perform geographical based analyses. Therefore, the data generated for EMAP-Wetlands will be georeferenced. Spatial analyses will be done on a GIS using ARC-INFO (Hewitt et al. unpub.). ARC-INFO is used by most of the federal and state agencies participating in the EMAP program. It is a powerful tool which includes extensive analytical capabilities and interfaces with a number of other major software products, including SAS and ERDAS (a common software tool for processing data collected by satellites). ARC-INFO is not user friendly; therefore, user friendly interfaces for routine data analysis and display will be developed by GIS team analysts. EMAP-Wetlands data analysts will work with other data management groups within EMAP and other agencies to develop standards and coverages for GIS applications. Standards will be developed for data accuracy, naming conventions, and documentation and archiving of completed maps.

9.4.7 Data Documentation

All data received by the WLIC will be converted into SAS data sets in the VAX system. Complete documentation of all databases stored in the WLIC is of paramount importance. The Data Set Index will be the principal data information source and will include a catalogue of all available data, modes of access, and quality of those data. A Data Library will be contained within the Data Set Index, which will also provide users with important information about the contents of each data set (e.g., variables measured, site locations). A Central Data Dictionary will document information on standards that have been developed for data sets which are generated by EMAP and for external data sets which have been processed to incorporate into the EMAP Information System. The standards will include field names, formats, documentation, acceptable ranges, and codes.

9.4.8 Existing Data

Existing data bases constitute an important source of information for developing the indicators, designing the sampling program, and interpreting the data. Databases identified as pertinent to the EMAP-Wetlands monitoring program will be included in the Data Set Index. All existing data integrated into the IMS will be converted, if necessary, to EMAP-Wetlands formats and standards.

9.5 QUALITY ASSURANCE FOR INFORMATION MANAGEMENT

Quality Assurance for information management includes those procedures that ensure that data entered into the system are of high quality. A program of this magnitude requires the utmost confidence in the validity of the final data bases.

Ensuring quality data begins with identifying sources of error in the data base system. There are essentially two general types of errors: (1) incorrect information and (2) missing, incomplete, or nonretrievable information (Kanciruk et al. 1986). Examples of errors of the first type include typographical errors, incorrect plant species identifications, and inaccurate instrument calibration. Although all errors cannot be completely eliminated through data management protocols, the potential for including incorrect information in the data base can be reduced. The second type of error is the omission of important information relating to a legitimate data value (Kanciruk et al. 1986). Such pieces of information, called "data qualifiers," assist in the correct interpretation of data values. Qualifying information will be anticipated and a structured system for recording and retrieving this information will be developed. The system will be designed with flexibility to allow for the inclusion of unanticipated qualifiers.

Quality Assurance and Information Management staff will work closely to develop an IMS to prevent corruption of data throughout all phases of activities. QA measures will be applied during field data collection, data transfer, sample tracking, data entry/verification, data validation, data analyses, archival and backup, and configuration management.

9.5.1 Field Data Collection and Verification

A systematic numbering system will be developed for unique identification of individual samples, sampling events, stations, shipments, equipment, and diskettes. Whenever possible, sample containers, equipment, and diskettes will be pre-labelled to eliminate confusion in the field. The pre-labelling will reduce the number of incorrect or poorly affixed labels. Eventually, bar code readers will be used to facilitate accurate sample number entry and identification in the field.

Standard operating procedures will document the use of field computer systems (data loggers) and the data entry procedures. Data loggers are hand held computers will display screens similar to manual field forms. They will automatically check for erroneous data being entered (e.g., range checks on numeric data and biological species code verification). Corrections can be made immediately on site. Data that have been flagged will be reviewed at a later date by QA personnel. Contingency plans using field forms will also be explicitly defined in the event that the field system fails. When manual entry is required, the data entry process will include an accuracy check by either double-entry or by a 100% visual verification. The method adopted will be determined by cost/benefit analysis.

At periodic intervals, field crews will back-up data collection in the field. Procedures for these field back-ups will be defined and crews trained in their use. Data will not be purged from the field computers until the information has been received at the central information center and a back-up copy made.

9.5.2 Laboratory Data Collection

Laboratories will be required to collect data and transmit it to a main repository. These data will include sample tracking information, results, and QA/QC information. Standard formats will be developed for data submitted electronically by the laboratories. Laboratories will be required to submit data in the required formats.

9.5.3 Data Transfer and Sample Tracking

Errors associated with entry and transcription will be minimized by electronic data capture. Transmitted data files will be verified for completeness and accuracy. If a file cannot be verified upon receipt (e.g., incorrect number of bytes), a new file transfer will be requested. Sample tracking systems will be designed that provide accurate information on the status and location of the samples.

9.5.4 Data Validation

Verified data will undergo validation analysis to identify and explain data outliers. The process involves association and multivariate analyses. All discrepancies which are identified will be documented and archived.

9.5.5 Archive and Backup

A database back-up system will be developed for complete and rapid recovery of all documentation in the event of a database system failure. Data entered, processed, and incorporated into the WLIC will be stored and archived long-term on redundant systems. This will ensure that if one system is destroyed or incapacitated, information management personnel will be able to reconstruct the data bases. Procedures will be developed to archive and recover the data if necessary. Several back-up copies of all data levels, and the programs used to process the data will be maintained. Back-ups of the entire system will be maintained off-site.

9.6 IMPLEMENTATION PLAN

The EMAP-Wetlands IMS will be implemented in several phases over a period of four years. The WLIC will be operational when a Wetlands Information Manager assumes control, basic information management systems are in place, and initial data collection activities have begun.

In FY91, activities will focus on designing an IMS for the field pilot study. EMAP-Wetlands will make use of existing resources to the extent possible, and will only acquire additional resources as necessary. EMAP-Wetlands resources will include EMAP and EPA staff, existing national and site contracts, EPA standard hardware and software, institutional resources (e.g., universities), and other agency resources. Initial prototypes of the field system, communications, and sample tracking data bases will be completed prior to the 1991 field season. These systems will undergo extensive testing and modification throughout the summer of 1991 after which the field computer systems, communications system, and data forms will be updated. Prototype data bases for indicator data will be created. These data bases will be used in preliminary data validation and verification. Appropriate modifications will be made during the winter 1991-92 in preparation for the 1992 regional demonstration project. An Information Program Plan and a System and Data Base Design Document will be produced.

In FY92, activities will expand areas of development and operation to complete a core system. External data will be integrated with EMAP-Wetlands data and analyses will be initiated. Prototype systems for electronic data access, the Data Set Index, and the Central Data Catalogue system will be designed and developed.

10.0 COORDINATION

As mentioned in Section 2.4, close cooperation with other federal agencies, interested groups, and other offices within EPA will be essential to achieve the EMAP-Wetlands objectives. Coordination with other programs will avoid duplicative monitoring efforts and allow existing data to be used to maximum benefit. Efforts that are ongoing or proposed relate to development of the network design, indicator selection and interpretation, and the logistics of field implementation. Each of these areas is discussed briefly in the following subsections. Table 10-1 provides an overview of all program coordination activities.

10.1 NETWORK DESIGN

The primary issues relating to network design that require coordination with other groups involve (1) frame development, (2) wetland classification, and (3) resource boundaries with other EMAP resource groups. Currently, an EMAP-Wetlands statistician is rigorously reviewing the NWI Status and Trends statistical frame for compatibility with EMAP's objectives. Options for EMAP-Wetlands frame development are being explored and both agencies plan to negotiate any statistical design changes deemed necessary for long-term joint monitoring and reporting of wetland acreage. Completion of the EMAP-Wetlands frame will require coordination among the EMAP-Wetlands program, NWI, and the EMAP-Landscape Characterization task group; these efforts are currently being pursued to ensure that portions of the EMAP-Wetlands frame are completed in time for the first EMAP-Wetlands regional demonstration project planned for 1992 (see Section 12).

The proposed EMAP-Wetlands classification scheme aggregates across a number of the Cowardin wetland classes used in the NWI (see Section 3.3). The USFWS and EPA will be working cooperatively during 1991 to evaluate this revised classification using several of the NWI's state digital wetland data bases (see Section 3.6).

EMAP-Wetlands will be working closely with other EMAP resource groups (Surface Waters, Near Coastal, Arid Lands, and Forests) to ensure that all important ecological resource classes are represented in EMAP and to avoid duplication. Issues being discussed include: (1) delineation of specific resource boundaries; (2) problems resulting from resource misclassifications that cross resource boundaries (see Section 3.5.4); (3) the potential for using a common Tier 2 sampling frame or for coordinated sampling of neighboring resources (e.g., sampling riparian wetlands along streams sampled by EMAP-Surface Waters) for special studies or some resource classes; and (4) general strategies for boundary coordination (discussed in Section 2.4).

10.2 INDICATORS

EMAP-Wetlands is negotiating cooperative biomonitoring efforts with the USFWS, the National Oceanic and Atmospheric Administration's (NOAA) Coastal Oceans Program (COP), the U.S. Army Corps of Engineers, USGS, other EMAP resource groups, the EPA Wetlands Research Program, and EPA's Office of Wetlands Protection. Historically, the USFWS has concentrated its monitoring efforts on contaminant concentrations in wildlife refuges. Recently, however, the USFWS has developed an interest in expanding its bioassessment activities because of its mandates to (1) protect threatened and endangered species and (2) manage and enhance national parks and wildlife refuges. EMAP and the USFWS are currently discussing long-term coordinated ventures to both develop bioassessment methodologies and monitor indicators of ecosystem condition.

Table 10-1. EMAP-Wetlands Coordination Activities.

Activities		Cooperators[a]	Status
Design			
	Frame	NWI	Cooperating with EMAP-Landscape Characterization to prepare the wetlands frame for the Southeast salt marshes.
		EMAP-LC	Preparing wetlands frame for the Southeast salt marshes.
	Classification	NWI	Evaluating the utility and representation of the EMAP classification in comparison with NWI state wetland data sets.
		Other EMAP	Working cooperatively with EMAP-Forests, Surface Waters, Near Coastal, and Great Lakes groups to define boundaries of respective EMAP groups.
Indicators			
	Site Specific	FWS	Developing bioassessment techniques-monitoring indicators of wetland health.
		Other EMAP	Planning for Riparian indicator pilot project and salt marsh pilot in Louisiana.
		WRP-MIT	Sharing the WRP's mitigation field protocols for similar field indicators.
		WRP-CON	Conducting a cooperative study to evaluate selected indicators of constructed wetland condition.
	Landscape	WRP-CI	Working cooperatively to produce and evaluate landscape pattern indicators for regional wetlands.
		COP	Developing the landscape indices for coastal wetlands.

[a]NWI = U.S. Fish and Wildlife Service's National Wetland Inventory, EMAP-LC = Landscape Characterization, WRP = EPA Wetlands Research Program, MIT = Mitigation, CON = Constructed Wetlands, CI = Cumulative Impacts, SCS = U.S. Department of Agriculture's Soil Conservation Service, Nature Conservancy EPA Region = EPA Regional Water Division Offices, State = State agencies involved in wetland protection monitoring activities, COP = National Oceanic and Atmospheric Administration's (NOAA) Coastal Ocean Program.

Table 10-1. (cont).

Activities		Cooperators[a]	Status
National Implementation			
	Interagency	FWS	Developing potential regional implementation of EMAP-Wetlands.
		SCS	Developing potential aid in obtaining access to wetland sites.
		Nature Conservancy	Developing potential implementation in monitoring rare and endangered species and communities.
	Regional	EPA REGION	Developing potential management of regional EMAP-Wetlands implementation.
		States	Developing potential personnel for field monitoring efforts.
Reporting		NWI	Planning for joint reporting of status and trends in wetlands condition and extent after the year 2005.

[a]NWI = U.S. Fish and Wildlife Service's National Wetland Inventory, EMAP-LC = Landscape Characterization, WRP = EPA Wetlands Research Program, MIT = Mitigation, CON = Constructed Wetlands, CI = Cumulative Impacts, SCS = U.S. Department of Agriculture's Soil Conservation Service, Nature Conservancy, EPA Region = EPA Regional Water Division Offices, State = State agencies involved in wetland protection monitoring activities, COP = National Oceanic and Atmospheric Administration's (NOAA) Coastal Ocean Program.

EMAP-Wetlands will be coordinating with the COP during the 1991 Gulf Coast salt marsh pilot to explore the feasibility of (1) using low elevation aerial photography to assist in interpreting field data and in assessing wetland condition and (2) testing and verifying remote sensing landscape indices as indicators of functional health for coastal wetland systems.

EMAP-Wetlands also will be working cooperatively with the COE in 1991 to field test selected EMAP-Wetlands indicators and sampling protocols at 36 COE sites.

USGS hydrologic stream gauging and ground water data will be used to assist in interpreting the instantaneous measures of water level and indirect hydrology indicators at EMAP-Wetlands sites (see Section 4.2.3).

EMAP-Wetlands will work cooperatively with other EMAP resource groups to address the following issues: (1) standard methods for measuring similar indicators (e.g., soil characteristics and water quality parameters); (2) development of multi-indicator indices of resource health; and (3) appropriate methods to distinguish effects from natural and anthropogenic stresses. Stressor indicators, landscape attributes, and commonly used metrics of community status, such as relative species abundance, will be measured by multiple EMAP resource groups using similar techniques. In addition, a common list of water quality and sediment contaminants will be identified and monitored by all resource groups.

Coordination with the Wetlands Research Program will occur in two phases. In the near term, EMAP-Wetlands will work cooperatively with the EPA Constructed Wetlands project to promote planning and implementation of a pilot study to evaluate the condition of selected constructed wetland sites. EMAP-Wetlands personnel will train staff working with the Constructed Wetlands project in the use and application of appropriate indicators of wetland condition. In the longer term, the Wetlands Research Team and EMAP-Wetlands will work together to define specific research needs and objectives, for more detailed site-specific research projects to be conducted by the Wetlands Research Team or other interested institutions, that would aid in the design of EMAP-Wetlands and interpretation of the monitoring results. Possible studies include: (1) detailed diagnostic analyses and quantification of dose-response relationships for EMAP-Wetlands exposure indicators; (2) quantification of seasonal and annual variability for indicators of wetland condition; (3) methods development and evaluation for indicators being considered by EMAP-Wetlands but that require further research (e.g., macroinvertebrate sampling); and (4) additional information on wetland functions and processes to aid in assessments of wetland health. Contacts will also be fostered with research and academic institutions who may be involved in indicator testing and development, temporal variability studies, and process research that may enhance EMAP-Wetlands diagnostic and assessment capabilities.

Other EPA offices and programs have also been contacted to solicit input on both the proposed EMAP design and indicator selection. Coordination with the Office of Wetlands Protection will ensure that EMAP-Wetlands addresses, to the degree possible, the informational needs of the EPA regional offices. The data collected by EMAP-Wetlands will contribute directly to the three primary objectives of the Office of Wetlands Protection, to maintain (1) a frequently updated physical inventory of wetlands, (2) the functional integrity of wetlands, and (3) landscape integrity.

10.3 IMPLEMENTATION

The implementation strategy for EMAP-Wetlands, defining priority wetland classes and regions for pilot studies and demonstration projects (see Section 12), was developed in consultation with the Office of Wetlands Protection, Office of Marine and Estuarine Protection, the EPA Regions, and other federal agencies (e.g., the USFWS) and organizations. EMAP-Wetlands will continue to involve these groups, as well as state agencies, in the planning and prioritization of field operations.

Recognizing that global climate change has the potential to overshadow all other stressor effects on wetlands, it will be imperative that EMAP-Wetlands coordinate their planning and implementation activities with the EPA Global Climate Program. The Global Climate Program will be compiling, collecting, and analyzing detailed national scale climatic data, which will be of use in interpreting patterns and trends in wetland structure and function.

EMAP-Wetlands will work closely with the U.S. Department of Agriculture SCS to gain access to wetland sites for field sampling, taking advantage of the SCS's extensive local network of offices and personnel. This arrangement will probably be formalized as an Interagency or Cooperative Agreement.

Two alternative management approaches are being considered for the eventual full-scale implementation of EMAP-Wetlands:

Option 1: Manage the program regionally through the EPA Regional Environmental Services Divisions or through contracts with university consortiums. These EMAP-Wetlands regional offices would oversee EMAP-Wetlands operations but may delegate field monitoring responsibilities to the states. The EMAP-Wetlands national office, working together with the regional offices, would be responsible for (1) establishing standardized methods and metrics for monitoring, (2) training the staff, (3) conducting QA activities and audits, and (4) integrating the data into regional and national reports.

Option 2: Establish a cooperative, interagency task force to maintain and manage the national program. Participants in this task force could include, if interested, the EPA, USFWS, U.S. Forest Service, NOAA, U.S. Army Corps of Engineers, the Nature Conservancy, and any other groups with a jurisdiction or interest in wetland resources. Regional offices would be maintained by a joint staff of Agency, Nature Conservancy, and contractor personnel. These joint regional offices would manage data collection in their regions and produce the required reports. The EMAP-Wetlands national office, working together with the joint regional offices, would be responsible for (1) establishing standardized methods and metrics for monitoring, (2) training the staff, (3) conducting QA activities and audits, and (4) integrating the data into regional and national reports.

11.0 EXPECTED OUTPUTS

The results from the EMAP-Wetlands monitoring program will be summarized in four types of documents:

1. Annual statistical summary reports,
2. Periodic interpretive reports,
3. Specialized scientific reports, and
4. Scientific articles in peer-reviewed journals.

Annual statistical summaries will be produced within nine months following collection of the last sample for the year. These reports will summarize the data for the preceding year, but include little interpretation.

Interpretative reports will be prepared for the Congress, interested scientists, and decision makers every 5 years, beginning after completion of the first sampling cycle. The goals of the interpretative reports will be to:

- Integrate information on stressor, habitat, exposure, and response indicators to determine the regional and national status of wetland acreage and condition;
- Identify likely causes of poor, deteriorating, or improving conditions in wetland acreage or health;
- Quantify trends in wetland acreage and condition;
- Identify emerging problems and their potential causes; and
- Assess the relationship between regulatory/control programs, such as "no net loss," and trends in the acreage and condition of wetland resources.

In the short-term, before the year 2005, the USFWS and EPA will produce **coordinated** reports on wetland extent and condition, respectively. These reports will be compatible, but will not be based on the same statistical design. This arrangement is necessary to allow each agency to meet its own short-term objectives. After 2005, joint interpretive reports will be produced from the NWI and EMAP-Wetlands.

Special scientific reports and peer-reviewed journal papers will be produced periodically to address and expand on topics of interest related to regional, stressor specific, or wetland-class specific issues. Special reports planned for 1991 include the following:

- A Pilot Project Plan, describing the proposed approach, design, and indicators to be monitored in 40 salt marshes in the Southeast (see Section 12);
- A Design Evaluation Report, assessing the proposed EMAP-Wetlands classification, grid density, site selection rules, and general adequacy of the EMAP design to meet the EMAP-Wetlands objectives; and
- A Standard Methods Manual for salt marshes, in support of the 1991 field pilot study, to ensure that EMAP-Wetlands data collection and analysis activities are consistently applied and are both accurate and precise.

12.0 FUTURE RESEARCH AND TIMELINES

The purpose of this chapter is to summarize the major research tasks and timelines required for the continued development and phased implementation of EMAP-Wetlands.

12.1 PROGRAM DEVELOPMENT

Three types of research activities have been identified in previous chapters to finalize the program design and approach prior to full-scale implementation:

1. Analysis of existing data and simulation studies,

2. Field pilot studies, and

3. Regional demonstration projects.

The major research objectives to be addressed by each are listed in Table 12-1.

Analyses of existing data sets and simulation studies will be initiated in fiscal year 1991 (FY91). In particular, a design evaluation study involving digitized wetlands data from the NWI for (1) the States of Illinois and Washington and (2) parts of the prairie pothole region will be completed by Fall 1991. Appropriate data sets for indicator development and evaluation (e.g., soils, vegetation biomass and species composition) also will be compiled and analyzed beginning in FY91. A trend simulation exercise will be conducted to assess the sensitivity of the EMAP design for detecting trends through time given the inherent background variability of wetland indicators. Efforts will focus initially on selecting and refining indicators for use in the first field pilot study planned for Louisiana salt marshes in late FY91.

Figure 12-1 and provides a schematic of the proposed strategy for field testing and implementing EMAP-Wetlands. The proposed timeline assumes adequate and timely funding to acquire and train the needed staff for program planning, implementation, and data analysis. The proposed approach is to sample one wetland class in one region, with a field pilot, followed by a regional demonstration, and finally full-scale implementation for the region and wetland class. Using this same sequence of pilot, regional demonstration, and implementation, the monitoring network is gradually scaled up by:

1. Monitoring the wetland class in additional regions, adding a new region each year until the wetland class is monitored nationally; and

2. Yearly additions of new wetland classes, starting in one region and gradually expanding to other areas.

At each phase, for each region and wetland class, the following support activities must be completed prior to initiation of field work:

- Sampling frame and site selection must be completed at least 9 months prior to each regional demonstration project and regional implementation, to initiate requests for access permission and development of the logistics plan.

- Research and Monitoring Plans must be prepared for each specific field pilot and regional demonstration project, to be ready for peer review at least 6 months prior to initiation and detailing (1) the indicators to be measured, (2) field sampling protocols and standard operating procedures, and (3) reference sites selected.

Table 12-1. EMAP-Wetlands: Proposed Research Tasks and Major Research Objectives.

Task	Major Research Objective: Design	Major Research Objective: Indicator/Field Sampling
1. Analysis of existing data simulation studies	o Compare EMAP to previous sampling grid designs o Assess efficiency of proposed wetland classification o Determine optimal tier 2 sample sizes o Finalize procedures for tier 2 site selection o Develop statistical algorithms for population estimation o Assess trend detection sensitivity	o Evaluate indicator responsiveness to major stressors o Quantify spatial and temporal variability o Initiate development of community metrics and evaluation o Identify indicators likely to relate to wetland condition, from previous studies
2. Field pilot	o Establish relation between indicator measurements and wetland condition (as defined by local experts) o Finalize procedures for selection reference sites o Assess proposed index period	o Evaluate indicator responsiveness to known stressors o Quantify spatial and temporal variability o Evaluate data interpretability relative to assessment endpoints o Test and refine sampling methods
3. Regional demonstration projects	o Evaluate adequacy of EMAP grid o Quantify errors associated with misclassification, boundary delineation, denied access	o Evaluate indicator applicability and interpretability on a regional scale o Obtain first EMAP outputs for regional assessment of wetland condition
4. Implementation	o Estimate regional status and trends	o Assess wetland condition on a regional scale

				PILOT Saturated Forest NORTHEAST
			PILOT Saturated Emergents MIDWEST	DEMO Saturated Emergents MIDWEST
		PILOT Bottomland Forest SOUTHEAST	DEMO Bottomland Forest SOUTHEAST	IMP Bottomland Forest SOUTHEAST
	PILOT Prairie Pothole MIDWEST	DEMO Prairie Pothole MIDWEST	IMP Prairie Pothole MIDWEST	IMP Flooded Emergents MIDWEST NORTHEAST
PILOT Salt Marsh LOUISIANA	DEMO Salt Marsh SOUTHEAST	IMP Salt Marsh SOUTHEAST	IMP Salt Marsh SOUTHEAST NORTHEAST	IMP Salt Marsh SOUTHEAST NORTHEAST WEST COAST
1991	1992	1993	1994	1995
1 FTE 5 Contract	4 FTE 6 Contract	5 FTE 9 Contract	8 FTE 11 Contract	11 FTE 11 Contract

PILOT = Pilot study
DEMO = Regional demonstration
IMP = Implementation
FTE = Full Time Equivalents
Contract = Contractor staff

Figure 12-1. Priority Research Needs and Time Frame for EMAP-Wetlands.

- o Interagency agreements, cooperative agreements, and contractual arrangements for planning and field sampling must be finalized well in advance of all proposed field activities.

In addition, procedures for data interpretation, in particular analysis techniques for assessing wetland health, nominal and subnominal condition, and diagnostics, must be ready by 1995, in time for the first EMAP-Wetlands Interpretive Report in 1996 following completion of the first four-year cycle for Southeast salt marshes.

The priority wetland classes and regions for phased testing and implementation are presented in Figure 12-1. In 1991, the first pilot study will be initiated in the coastal marshes of Louisiana. Southeastern salt marshes were selected as the highest priority wetland class and region for the following reasons:

1. It is estimated that over 100 km^2 of Louisiana coastal marshes are lost each year (Fruge 1982) as a result of coastal subsidence, channelization, and salt water intrusion;

2. The EMAP-Near Coastal resource group will be conducting a regional demonstration project in the Southeast in 1991, allowing for cooperative planning and sampling efforts between the two EMAP resource groups; and

3. Work in the Louisiana coastal salt marshes will be conducted cooperatively with NOAA's COP to test the feasibility of using remote sensing indices of functional health to verify interpreted ground level data.

Preparation of the Pilot Study Plan and field activities will require approximately three staff, in addition to the three currently comprising the EMAP-Wetlands group. New staff members will be selected to provide expertise in statistics, data management, data analysis, and technical support. The EMAP-Wetlands staff will increase, therefore, in FY91 to a total of six.

In 1992, field activities in Southeast salt marshes will be expanded to a regional demonstration project. As part of this demonstration project, sampling and analyses will be conducted to (1) assess the effectiveness of the proposed index period for field sampling and (2) quantify regional intra- and inter-site indicator variability. In addition, a second pilot study will be conducted in flooded emergent wetlands (prairie potholes) of the Midwest. Prairie potholes in the Midwest were selected as second priority for EMAP-Wetlands for the following reasons:

1. Prairie potholes are the most valuable inland marshes for waterfowl production in North America (Tiner 1984);

2. The extent and condition of this wetland resource have declined dramatically in recent years. In some states, half of the prairie potholes have been lost as a result of agriculture, irrigation, and flood control projects (Tiner 1984); and

3. EPA's Office of Wetlands Protection, the USFWS, the Nature Conservancy, and Ducks Unlimited have expressed a high level of interest in obtaining additional information on the status and trends in condition of these systems.

Four additional staff will be required to prepare a new Pilot Study Plan and conduct field activities associated with this second pilot. The total number of staff members will increase to ten.

In 1993, plans call for a third pilot study of flooded forested wetlands (bottomland hardwood wetlands) in the Southeast, an expansion of the emergent wetland pilot to a regional demonstration in the Midwest, and expansion of the salt marsh demonstration to full implementation for the wetland class in the Southeast. Flooded forested wetlands were selected as the third priority wetland class for the following reasons:

1. Over 70% of the pre-settlement bottomland hardwood wetlands in the Southeast have been channelized, cleared, and converted for agricultural use (Brinson et al. 1981, Tiner 1984);

2. EPA's Office of Wetlands Protection and the USFWS have expressed a high level of interest in obtaining additional information on the status of this resource; and

3. Sampling in bottomland hardwoods will provide the opportunity for a cooperative effort with the EMAP-Forests resource group, the U.S. Forest Service (Forest Inventory Assessment), and other federal and state agencies.

Four additional staff will be required to prepare a new Pilot Study Plan and conduct field activities associated with the new pilot study. Thus, the EMAP-Wetlands staff will increase to a total of fourteen.

In 1994, activities will include a pilot study of saturated emergent wetlands in the Midwest, an expansion of the forested wetland pilot to a regional demonstration for the Southeast, an expansion of the flooded emergent regional demonstration to full implementation in the Midwest, and expansion of the salt marsh implementation monitoring to the Northeast. Saturated emergent wetlands were selected as the fourth priority wetland class because of interest in these systems by EPA's Office of Wetland Protection, the USFWS, the Nature Conservancy, and Ducks Unlimited. At this time, it is assumed that the three staff added to conduct the first pilot (1991) have progressed through demonstration (1992) and full implementation (1993) and have handed off further responsibility to a local group with the interest and expertise to continue the program. Consequently, these three staff members are assumed to be available to plan and conduct the new pilot; but, they will be replaced by regional staff, and two new staff will be added to conduct the new pilot. Thus, the EMAP-Wetlands staff will increase to a total of sixteen.

In 1995, activities will include a pilot study of saturated forested wetlands in the Northeast, an expansion of the saturated emergent pilot to a regional demonstration in the Midwest, an expansion of the flooded forested wetland demonstration to full implementation in the Southeast, and implementation of flooded emergents in the Northeast and salt marshes on the West Coast. Further, by this time the amount of data generated by the program will have increased the need for both data management and analysis. In addition, coordination and QA needs will have increased as local groups have accepted responsibility for continuing the program in their regions. In 1995, data analyses will be initiated to produce resource assessments and preliminary diagnostic interpretations. Consequently, six more individuals will be added to the staff, bringing the total to twenty-two.

By 1995, EMAP-Wetlands will have incorporated five wetland classes into the program at least through the pilot phase. By 1997, each of these five priority wetland classes will have progressed to full implementation in at least one region. The process of selecting local groups with both interest and expertise to continue the operational aspects of the program will have been developed and will have been implemented in six regions. The first interpretive report describing the condition of coastal wetlands is scheduled for completion in 1996.

12.2 IMPLEMENTATION

The ultimate goal of EMAP-Wetlands is to develop a program to monitor the condition of the Nation's wetlands and implement it on a national scale. Recognizing that knowledge of the condition of wetlands is as important locally as it is nationally, state and local agencies will undoubtedly be interested in expanding the EMAP program/strategy to meet local and site specific needs. As the program develops, depending on the response of state and other federal agencies, a decision will be made to implement the program as an interagency project carried out by regional offices staffed by the agencies involved, or as an EPA program carried out by funding state agencies to collect the required data (See Section 10.3). This decision may be made as early as 1993, when the salt marsh demonstration is ready for implementation according to the EMAP design in the Southeast region, or as late as 1995 when the salt marsh program is implemented in all regions and other classes are ready for implementation in selected regions. Regardless which decision is made, it will remain the responsibility of the EMAP-Wetlands program to select and improve on indicators, standardize site selection, standardize measurement techniques, audit performance of all groups involved in data acquisition, and interpret and report results.

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APPENDIX A

United States
Environmental Protection
Agency

Office of Modeling,
Monitoring Systems and
Quality Assurance (RD-680)
Washington DC 20460

Research and Development
EPA/600/9-90/001 January 1990

EPA

Environmental Monitoring and Assessment Program

Overview

Overview

This document presents an overview of the rationale, goals, and primary elements of the Environmental Monitoring and Assessment Program (EMAP), which represents a long-term commitment to assess and document periodically the condition of the Nation's ecological resources. EMAP is being designed by the U.S. Environmental Protection Agency's (EPA) Office of Research and Development. The program will serve a wide spectrum of users: decision-makers who require information to set environmental policy; program managers who must assign priorities to research and monitoring projects; scientists who desire a broader understanding of ecosystems; and managers and analysts who require an objective basis for evaluating the effectiveness of the Nation's environmental policies.

Monitoring, Regulatory, & Policy Needs

Environmental regulatory programs have been estimated to cost more than $70 billion annually, yet the means to assess their effect on the environment over the long term do not exist. While regulatory programs are based upon our best understanding of the environment at the time of their development, it is critical that long-term monitoring programs be in place to confirm the effectiveness of these programs in achieving their environmental goals and to corroborate the science upon which they are based.

The EPA, the U.S. Congress, and private environmental organizations have long recognized the need to improve our ability to document the condition of our environment. Congressional hearings in 1984 on the National Environmental Monitoring Improvement Act concluded that, despite considerable expenditures on monitoring, federal agencies could assess neither the status of ecological resources nor the overall progress toward legally-mandated goals of mitigating or preventing adverse ecological effects.. In the last decade, articles and editorials in professional journals of the environmental sciences have repeatedly called for the collection of more relevant and comparable ecological data and easy access to those data for the research community.

Affirming the existence of a major gap in our environmental data and recognizing the broad base of support for better environmental monitoring, the EPA Science Advisory Board (SAB) recommended in 1988 that EPA initiate a program that would monitor ecological status and trends, as well as develop innovative methods for anticipating emerging problems before they reach crisis proportions. EPA was encouraged to become more active in ecological monitoring because its regulatory responsibilities require quantitative, scientific assessments of the complex effects of pollutants on ecosystems. EMAP is being initiated in 1990 by EPA in response to these recommendations.

EMAP's Purpose

EMAP is being designed to monitor indicators of the condition of our Nation's ecological resources. Specifically, EMAP is intended to respond to the growing demand for information characterizing the condition of our environment and the type and location of changes in our environment. Simultaneous monitoring of pollutants and environmental changes will allow us to identify likely causes of adverse changes. When fully implemented, EMAP will answer the following questions:

- ❑ What is the current status, extent, and geographic distribution of our ecological resources (*e.g.*, estuaries, lakes, streams, wetlands, forests, grasslands, deserts)?
- ❑ What proportions of these resources are degrading or improving, where, and at what rate?
- ❑ What are the likely causes of adverse effects?
- ❑ Are adversely-affected ecosystems responding as expected to control and mitigation programs?

EMAP will provide the Administrator, the Congress, and the public with statistical data summaries and periodic interpretive reports on ecological status and trends. Because sound decision-making must consider the uncertainty associated with quantitative information, all EMAP status and trends estimates will include statistically-rigorous confidence limits.

Assessments of changes in our Nation's ecological resource conditions require data on large geographic scales collected over long periods of time. For national assessments, comparability of data among geographic regions (*e.g.*, the Northeast, Southeast, and West) and over extended periods is critical, and meeting this need by simply aggregating data from many individual, local, and short-term networks that are fragmented in space or time has proven difficult, if not impossible. EMAP will focus specifically on national and regional scales over periods of years to decades, collecting data on indicators of ecological condition from multiple ecosystems and integrating them to assess environmental change. This approach, along with EMAP's statistically-based design, distinguishes it from most current monitoring efforts, which tend to be short-term or locally-focused. A long-term, integrated, multi-ecosystem monitoring program offers the advantages of earlier detection of problems and improved resolution of their extent and magnitude, while enabling formulation of more cost-effective regulatory or remedial actions.

Environmental monitoring data are collected by EPA to meet the requirements of a variety of regulatory programs. Many federal agencies collect environmental data specifically to manage particular ecological resources. Efficient execution of EPA's mandate to protect the Nation's ecosystems requires, therefore, that EMAP complement, supplement, and integrate data and expertise from the regulatory offices within EPA and from other agencies. EMAP should not be perceived as a substitute for ongoing programs designed to meet objectives other than its own. Interagency coördination is actively being pursued with the Departments of Interior, Commerce, and Agriculture. This coördination avoids duplicative monitoring efforts, facilitates exchange of existing data for use in the refinement of monitoring networks, and increases the expertise available to quantify and understand observed status and trends. EMAP will also draw upon the expertise and activities of the EPA Regional Offices, States, and the international community.

Ecological monitoring programs of the 1990's and beyond must be able to respond and adapt to new issues and perspectives within the context of a continuing effort to detect trends and patterns in environmental change. These demands will be met by EMAP through a flexible design that can accommodate as yet undefined questions and objectives as well as changing criteria of performance and scientific capability. Further, EMAP's design will encourage analysis, review, and reporting processes that foster discovery of unanticipated results and promote the widespread dissemination of scientifically-sound information. Periodic evaluations of the program's direction and emphasis will be the key to maintaining its viability and relevance while retaining the continuity of the basic data sets. These evaluations will serve to preclude the "aging" that typically hinders long-term monitoring efforts.

Planning & Design

The major activities in 1990 around which EMAP is being developed are:

- ❑ **Indicator Evaluation and Testing**—evaluation and testing of indicators of ecological condition;
- ❑ **Network Design**—design and evaluation of integrated, statistical monitoring networks and protocols for collecting status and trends data on indicators;
- ❑ **Landscape Characterization**—nationwide characterization of ecological resources in areas within the EMAP sampling network to establish a baseline for monitoring and assessment; and
- ❑ **Near-Coastal Demonstration Project**—implementation of regional-scale surveys to define the current status of our estuarine resources.

Although the goal is to establish the program in all categories of ecosystems, the initial emphasis is on testing and implementing the program in estuaries, near-coastal wetlands, and inland surface waters, coördinating these activities with the National Oceanic and Atmospheric Administration, the U.S. Fish and Wildlife Service, and the U.S. Geological Survey. Because precipitation and air quality are two important factors influencing ecosystems, EMAP also will contribute to the evaluation and maintenance of the multiägency atmospheric deposition networks currently coördinated by the National Acid Precipitation Assessment Program (*i.e.*, the National Trends Network/National Dry Deposition Network). These ecosystems and deposition networks offer immediate opportunities to demonstrate the EMAP approach.

EMAP also will contribute to the development of a research program in environmental statistics. This program will refine the statistical framework for the remaining types of ecosystems in preparation for full implementation of EMAP in 1995 and beyond. Relying heavily on expertise from academia and industry, this program will develop methods and approaches for: *(a)* analyzing and interpreting spatial and temporal trends in indicators across regions; *(b)* incorporating and substituting historical data and data from ongoing monitoring programs into EMAP; *(c)* designing efficient quality assurance programs for ecological monitoring programs; and *(d)* diagnosing the likely causes of adverse conditions in ecosystems.

Indicator Evaluation & Testing

Purpose

EMAP will evaluate and use indicators that collectively describe the overall condition of an ecosystem. Measurements of ecosystem condition should reflect characteristics clearly valued by society. Measurement methods must be standardized and quality-assured so that spatial patterns and temporal trends in condition within and among regions can be accurately assessed.

Strategy

Indicators in three categories will be evaluated:

- **Response indicators**—which quantify the response of ecosystems to anthropogenic stress. Examples include signs of gross pathology (*e.g.*, the appearance of tumors in fish or visible damage to tree canopies); the status of organisms that are particularly sensitive to pollutants or populations of organisms important to sportsmen, commercial interests, or naturalists; and indices of community structure and biodiversity.

- **Exposure indicators**—which show whether ecosystems have been exposed to pollutants, habitat degradation, or other causes of poor condition. Examples include ambient pollutant concentrations; acidic deposition rates; bioaccumulation of toxics in plant and animal tissues; media-specific field bioassays using test organisms; and measurements of habitat condition or availability (*e.g.*, siltation of bottom habitat and vegetative canopy complexity).

- **Stressor indicators**—which are socio-economic, demographic, and regulatory compliance measurements that are suggestive of environmental stress. Examples include coal production, population figures, pesticide applications, pollutant emissions inventories, and land use.

Sets of indicators will be identified and measured in all categories for each ecosystem type. The set of response indicators should reflect adverse effects of both anticipated and unanticipated environmental stresses (*e.g.*, new pollutants). Criteria must be developed for each response indicator to identify when conditions change from acceptable or desirable to unacceptable or undesirable. Criteria could be based on conditions attainable under best management practices as observed at "regional reference sites", relatively undisturbed sites that are typical of an ecoregion. A set of exposure indicators will be used to determine whether ecosystems have been exposed to environmental stress and what the causes of poor condition are likely to be. For example, undesirably low diversity in stream fish communities across a region might be related to the presence of toxics in sediments, siltation of bottom habitat, insufficient flow, low pH, or bioaccumulation of toxics. In this example, stressor indicators that might be examined in diagnosing the cause would include the number and type of industrial dischargers, farmed acreage or construction activity, water withdrawals, presence of mine spoils or acidic deposition, and regional pesticide application.

The goals of EMAP are quite different from those of the compliance monitoring most commonly conducted by EPA. While compliance monitoring involves identifying, with a high degree of confidence, pollutant concentrations that can be linked unequivocally to individual polluters, EMAP will use sets of indicators to assess the condition of multiple ecological systems across regions, coupled with an evaluation of associated pollutant sources or other anthropogenic environmental disturbance. EMAP's regional approach to environmental monitoring and assessment is quite unusual, and the expected benefits include an improved capability to detect emerging problems and to identify those types of ecosystems most in need of research, assessment, or remediation. Regional monitoring and assessment is the only effective way to determine whether current environmental regulations are adequately protecting our ecological resources.

Activities

Many scientific questions remain to be answered. Is the natural variability in response indicators too large to make sufficiently precise estimates of regional conditions? Can ecosystem condition be compared among regions with differing biota? What criteria will be used to determine acceptable versus unacceptable conditions? How are the data best interpreted for systems with response indicators in undesirable ranges and multiple, conflicting, or unknown exposure indicators? What, if anything, might be done when a system's range in response indicators is acceptable, but the range in exposure indicators is not? EMAP will seek short- and long-term answers to these questions through three types of activities:

- Reports evaluating the availability and applicability of indicators for all EMAP ecosystem categories;

- Workshops on ecological indicators; and

- Development of a long-term indicator research program for all EMAP ecosystem categories.

Network Design

Purpose

Meeting the goal of estimating status and trends in the condition of the Nation's ecosystems requires a monitoring framework that:

- Provides the basis for determining and reporting on ecological indicators at various geographic scales;

- Is adaptable to monitoring on regional as well as on continental and global scales;

- Enables the examination of correlations among spatial and temporal patterns of response, exposure, and stressor indicators;

- Enables the incorporation or substitution of data from ongoing monitoring sites and networks; and

- Is sufficiently adaptable and flexible to accommodate changes in spatial extent of the resource (*e.g.*, the areal extent of wetlands) and to address current and emerging issues.

Strategy

A global grid will be constructed for identifying sampling sites. This grid will then be divided into sub-grids in accordance with whatever scale of resolution (*e.g.,* national, regional, or subregional) is required for an assessment of the condition of ecological resources. Currently, a sub-grid for the United States and its surrounding continental shelf waters that includes approximately 12,500 sites is being evaluated. Within these sites, ecosystems will be identified and characterized and their their number and areal extent will be determined. This initial characterization will be accomplished using existing maps, satellite imagery, and aerial photography. Field sampling of sets of indicators will be conducted on a subset of sites statistically selected from the 12,500 original sites.

Current EMAP research will determine the number of sampling sites needed for regional and national reports on the status, changes, and trends in indicators. Two alternative approaches for field sampling of approximately 3,000 sites are being considered. In the first, about one-fourth of the 3,000 sites across the continental United States would be visited in one year. The following year, a second one-fourth of the sites would be sampled and so on, such that all sites would be visited during a four-year period. In the second, data would be collected during a single year at all the sampling sites in a geographical area (*e.g.,* the estuaries in the Virginian Province from Cape Cod to Cape Hatteras or all lakes and streams in the Northeast) and sampling efforts would shift to a new area during following years. The statistical, logistical, and reporting advantages of each option are being evaluated in light of EMAP's long-term goal to provide a national assessment of the status, changes, and trends in ecological resources. In addition, the timing of the sampling period, the statistical procedures for establishing where a measurement is to be made, and the number of samples that must be collected at each sampling site are being examined.

Activities

Current activities are focused on making the global grid final, applying it to the United States, and identifying rules for associating ecosystems with grid points and statistically selecting them for sampling. The EMAP design and sampling strategy will be reviewed by the American Statistical Association and appropriate ecosystem experts.

Landscape Characterization

Purpose

National assessments of status and trends of the condition of ecosystems require knowing not only what percentage of a particular resource is in desirable or acceptable condition, but also how much of that resource exists. Some types of wetlands are being lost at an alarming rate; conversion and loss of other types of ecosystems are also occurring. Such changes may be of particular concern if statistically correlated with pollutant exposure or other anthropogenic stressors. For most ecosystems, few national data bases can currently be used to derive quantitative estimates of ecosystem extent and changes in condition on a regional basis with known confidence.

The technique that will be used to address these issues is landscape characterization. Landscape characterization is the documentation of the principal components of landscape structure—the physical environment, biological composition, and human activity patterns—in a geographic area. EMAP will characterize the national landscape by mapping landscape features (*e.g.,* wetlands, forests, soils, and land uses) in areas associated with the EMAP sampling grid. Characterization uses remote sensing technology (satellite imagery and aerial photography) and other techniques (*e.g.,* cartographic analysis and analysis of census data) to quantify the extent and distribution of ecosystems. Over time, periodic aerial and satellite photography will permit quantitative estimation of changes in landscape features that might be related to anthropogenic activities and pollutants. The results of these characterization analyses also permit more informed selection of systems for field sampling.

Strategy

The characterization strategy involves the application of remote sensing technology to obtain high-resolution data on selected sample sites and lower resolution data over broad geographical areas. Other data sources such as maps and censuses will be used to supplement the remote sensing data.

The remote sensing data also will furnish detailed information needed for the network design. For example, lakes, streams, wetlands, forests, and other types of ecosystems associated with each grid point will be identified so that a subset for field sampling can be statistically selected. Characterization also supplies a portion of the data needed to classify ecosystems into subcategories of interest (e.g., forest-cover types, wetland types, crops, and lake types).

Certain types of landscape data assist in diagnosing the probable causes of undesirable conditions in response indicators. Characterization will describe the physical and spatial aspects of the environment that reflect habitat modification, for example, those that can amplify or counteract the effects of toxicants and other pollutants on plants and animals.

Finally, characterization will compile data on stressor indicators that can be identified from remote sensing and mapped data, including land use, mining activities, population centers, transportation and power corridors, and other anthropogenic disturbances.

EMAP will assemble, manage, and update these data in Geographic Information System (GIS) format. A standardized characterization approach and a landscape information network common to all ecosystems will be used to optimize cost and data sharing and to ensure common format and consistency. Through close work with other agencies, EMAP will establish design requirements for the integrated characterization including acceptance criteria for baseline data, consistent classification detail and accuracy, and suitable spatial and temporal resolution to distinguish landscape features of particular interest.

Activities

The design of the characterization plan and the evaluation of potential characterization techniques are in progress. A prototype methodology for high-resolution characterization has been developed. Current activities include evaluating a range of methods, from landscape ecology to quantitative, multistage remote sensing (combined satellite and aerial photography) in widely different terrain types. EMAP characterization will begin in 1990 at approximately 800 sites, or about one-fourth of the 3,000 selected for field sampling.

Near-Coastal Demonstration Project

Purpose

Information obtained from the near-coastal demonstration project will be used to refine the EMAP design, and the study itself will serve as a model for implementing EMAP projects in other study areas and types of ecosystems.

The demonstration project has five goals:

- ❑ Evaluate the utility, sensitivity, and applicability of the EMAP near-coastal indicators on a regional scale;
- ❑ Determine the effectiveness of the EMAP network design for quantifying the extent and magnitude of pollution problems in the near-coastal environment;
- ❑ Demonstrate the usefulness of results for planning, priority-setting, and determining the effectiveness of pollution control actions;
- ❑ Develop standardized methods for indicator measurements that can be transferred to other study areas and made available for other monitoring efforts; and
- ❑ Identify and resolve logistical issues associated with implementing the network design.

Strategy

The strategy for accomplishing the above tasks is to work closely with the National Oceanic and Atmospheric Administration's National Status and Trends Program to field-test the near-coastal indicators and network design through a demonstration study in the estuaries and coastal wetlands of the Mid-Atlantic area of the United States. Estuaries were selected because their natural circulation patterns concentrate and retain pollutants. Estuaries and coastal wetlands are also spawning and nursery grounds for many valued living resources, and estuarine watersheds receive a large proportion of the pollutants discharged to the Nation's waterways. The Mid-Atlantic study area was chosen because adverse pollutant impacts are evident; contaminants are present in the water, sediments, and biota; the vitality of many organisms is reportedly threatened; and seven of the area's larger estuaries are included in EPA's National Estuary Program.

Activities

During 1989, the major environmental problems associated with near-coastal systems were identified: eutrophication, contamination, habitat modification, and the cumulative impact of multiple stressors. A set of response, exposure, and stressor indicators applicable to each problem is to be identified, based on current understanding of how various environmental stressors affect ecosystem processes and biota. Near-coastal ecosystems have been classified for monitoring and assessment based on their physical and chemical characteristics and their susceptibility to environmental stressors. A monitoring network design that is compatible with the EMAP design is being developed. Several logistical and technical questions regarding the EMAP near-coastal project remain, including:

- ❑ What set of indicators will be measured?
- ❑ What specific methods will be used to sample each indicator?
- ❑ Will all indicators be measured at all sampling sites or can a sampling plan be developed that requires measurement of costly indicators only at selected sites? and
- ❑ To what degree should sources of variation be measured and accounted for in the network design?

The near-coastal demonstration project will be conducted in the estuaries and coastal wetlands of the mid-Atlantic area of the United States (from Cape Hatteras to Cape Cod) during mid-1990. A report on the results of the project will be prepared in 1991.

Information Contact

EMAP is planned and managed by ORD's Office of Modeling, Monitoring Systems, and Quality Assurance (OMMSQA). Inquiries may be directed to:

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APPENDIX B

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PROPOSED EMAP-WETLANDS WETLAND CLASSIFICATION: DEFINITIONS OF WETLAND CLASSES

Each of the proposed Tier 1 wetland systems and classes are briefly defined below. The following definitions have been based in part on the definitions provided in Cowardin et al. (1979), Mitsch and Gosselink (1986), Lugo et al. (1988), and USFWS (1981), and rationale provided by B. Wilen and R. Sullivan (USFWS and Bionetics, respectively, pers. comm.).

Wetland: "Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. Wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes, (2) the substrate is predominantly undrained hydric soils, and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of the year" (Cowardin et al. 1979). For our purposes, the target population of EMAP-Wetlands will include all palustrine, riverine, lacustrine, and estuarine wetlands with greater than 30% wetland vegetation cover which can be identified using 1:40,000 aerial imagery. Thus, EMAP wetlands are a subset of the jurisdictional wetlands as defined by the recent wetland identification criteria (Federal Interagency Committee for Wetland Delineation 1989).

The hierarchy of the wetland classification and definitions will be as follows:

SYSTEM	WATER SOURCE MODIFIER	WATER REGIME
Palustrine		
	Lacustrine modifier (L)	Temporary Flooded
	Riverine modifier (R)	Saturated
	No modifier (basin)	Seasonal Permanent Flooded
Estuarine		

The EMAP-Wetlands systems and modifiers are defined below. Note that the Lacustrine and Riverine systems have been folded into the Palustrine system to account for the importance of the dominant water source to a wetland. The definitions and rules listed below are deemed to be the least arbitrary means of creating a distinction between isolated Palustrine wetlands and wetlands that are flooded by moving waters from either Riverine or Lacustrine systems.

I. **Palustrine wetlands** include all non-tidal fresh and saline wetlands dominated by trees, shrubs, emergents, or shallows (aquatic beds, mudflats, and open water areas), and all such wetlands that occur in tidal areas where salinity due to ocean derived salts is < 0.5%. Palustrine wetlands have been subdivided into basin, riparian, or lake influenced systems.

Palustrine/L Locator (PL) wetlands are all wetlands adjacent to a lake, including persistent and non-persistent emergent, forested, or scrub-shrub wetlands adjacent to a Limnetic or Littoral Lacustrine system. These PL wetlands have been aggregated into one class due to the small portion of all wetland classes (in number and acreage) they represent.

Palustrine/R Locator wetlands are all wetlands adjacent to a river and included within a floodplain. Thus, these wetlands share a common boundary with the Riverine System's

Tidal, Lower Perennial, Upper Perennial, or Unknown Perennial subsystems. This modified system includes all emergents and forests/scrub-shrubs along river systems. The Riverine system terminates when the salinity from ocean derived downstream salts exceeds 0.5% or where the channel enters a lake or Palustrine wetland.

All wetlands with Riverine tidal water regimes (Temporary Tidal, Seasonal Tidal, or Semipermanent Tidal) will also be labeled with a Riverine locator, even if not immediately adjacent to the Riverine system polygon. The riverine flooding influence is expected to dominate the tidal influence in these settings.

The Riverine locator takes precedence when a Palustrine wetland is adjacent to both a Riverine and Lacustrine system. The Riverine locator is given priority because flood waters from a river generally produce more dynamic effects on a wetland and occur with greater frequency than do flood waters which result from water level changes in a lake.

Palustrine (no locator) wetlands include all Palustrine wetlands that do not share a common boundary with a river, lake, or tidal system. These wetlands are deemed to be isolated basin wetlands, influenced primarily by precipitation. This group includes the following classes: shallows, emergents, and forest/scrub-shrub.

II. **Estuarine Wetlands** include tidal wetlands that are semi-enclosed by land but have open, partly obstructed, or sporadic access to the open ocean, and in which ocean water is at least occasionally diluted by freshwater runoff from the land. The landward limit of the Estuarine system is where salinity is less than 0.05% during average annual low flow. EMAP-Wetlands estuarine wetlands include the emergents and forested/scrub-shrub mixes that occur in this setting.

Described below are the classes and subclasses (denoted by water regimes) in the EMAP-Wetlands classification.

	Classes		Subclass
1	Shallows		
		1a	Aquatic Beds
		1b	Mudflats (unconsolidated shore)
		1c	Other sparsely vegetated areas/open water (unconsolidated bottom)
2	Emergent		
		2a	Temporary Flooded
		2b	Saturated
		2c	Seasonal-Permanent Flooded
3	Forest and Scrub-shrub		
		3a	Temporary Flooded
		3b	Saturated
		3c	Seasonal-Permanent Flooded

1. **Shallows** are areas of shallow open water (to 2 m deep) dominated by submerged or floating leaved aquatic beds and (or) the zone between low and high water that includes both sand flats and other mudflats. According to the Cowardin classification system, this includes the aquatic beds, unconsolidated shore, and unconsolidated bottom, as well as open water areas that are not part of the Lacustrine system (Frayer et al. 1983). Shallows in the EMAP-Wetlands classification occur only in the Palustrine basin type wetlands. Shallows along lakes and rivers are presumed to be monitored by the EMAP-Surface Waters resource group. Estuarine shallows will be monitored by the EMAP-Near Coastal resource group. Shallows are an aggregate grouping of the following Cowardin subclasses.

   1a. **Aquatic Beds** are wetlands and deepwater habitats dominated by macrophytic plants that grow principally on or below the surface of the water for most of the growing season in most years.

   1b. **Mudflats** are unconsolidated shores including all wetland habitats with (1) unconsolidated substrates (predominantly silt, sand, and clay) with less than 75% areal cover of stones, boulders, or bedrock; (2) less than 30% areal cover of vegetation other than pioneering plants; and (3) any of the following water regimes: irregularly exposed, regularly flooded, irregularly flooded, seasonally flooded, temporally flooded, intermittently flooded, saturated, or artificially flooded.

   1c. **Other Open Water Areas** include small (0-12 ha), shallow (0-2 m) saline or fresh natural surface depressions that act as precipitation catchment basins, but are often ephemeral, because of high evapotranspiration rates. These areas are not densely vegetated (have less than 30% vegetation) and include some wetlands within the colloquial classes of prairie potholes, playa lakes, and ponds that are open water with little vegetation. This subclass is mapped as unconsolidated shore by the NWI.

2. **Emergent wetlands** are characterized by erect, vascular, rooted, and herbaceous hydrophytes. The primary emergent sub-classes are temporary flooded, saturated, and seasonal-permanent flooded.

   2a. **Temporary Flooded** emergent wetlands include the erect, vascular, rooted herbaceous hydrophytes growing in intermittently flooded, temporary flooded, and temporary tidal soil conditions as defined by Cowardin et al. (1979).

   2b. **Saturated** emergent wetlands include the erect, vascular, rooted, herbaceous hydrophytes growing in saturated and seasonally saturated soil conditions as defined by Cowardin et al. (1979).

   2c. **Seasonal-Permanent Flooded** emergent wetlands include the erect, vascular rooted herbaceous hydrophytes growing in Seasonal Flooded, Semipermanently Flooded, Intermittently exposed, Permanently Flooded, Seasonal Tidal, and Semipermanent Tidal soil conditions as defined by Cowardin et al. (1979).

3. **Forested/Scrub-Shrub wetlands** are dominated by a mixed community of woody vegetation consisting of primarily shrubs and trees. Shrubs are defined as woody vegetation less than 6 meters (20 feet) tall. Species include true shrubs, young trees, and trees and shrubs with stunted growth because of environmental conditions. Trees are characterized by woody vegetation 6 meters tall or taller. In the Estuarine system, this class will be used to characterize mangroves. In the Palustrine system, this class occurs in temporary flooded, saturated, and seasonal-permanent flooded soil conditions.

3a. **Temporary Flooded** forest/scrub-shrub wetlands include a mixed community of woody vegetation growing in intermittently flooded, temporary flooded, and temporary tidal soil conditions as defined by Cowardin et al. (1979).

3b. **Saturated** forest/scrub-shrub include a mixed community of woody vegetation growing in saturated and seasonally saturated soil conditions as defined by Cowardin et al. (1979).

3c. **Seasonal-Permanent Flooded** forest/scrub-shrub include a mixed community of woody vegetation growing in Seasonal Flooded, Semipermanently Flooded, Intermittently Exposed, Permanently Flooded, Seasonal Tidal, and Semipermanent Tidal soil conditions as defined by Cowardin et al. (1979).

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