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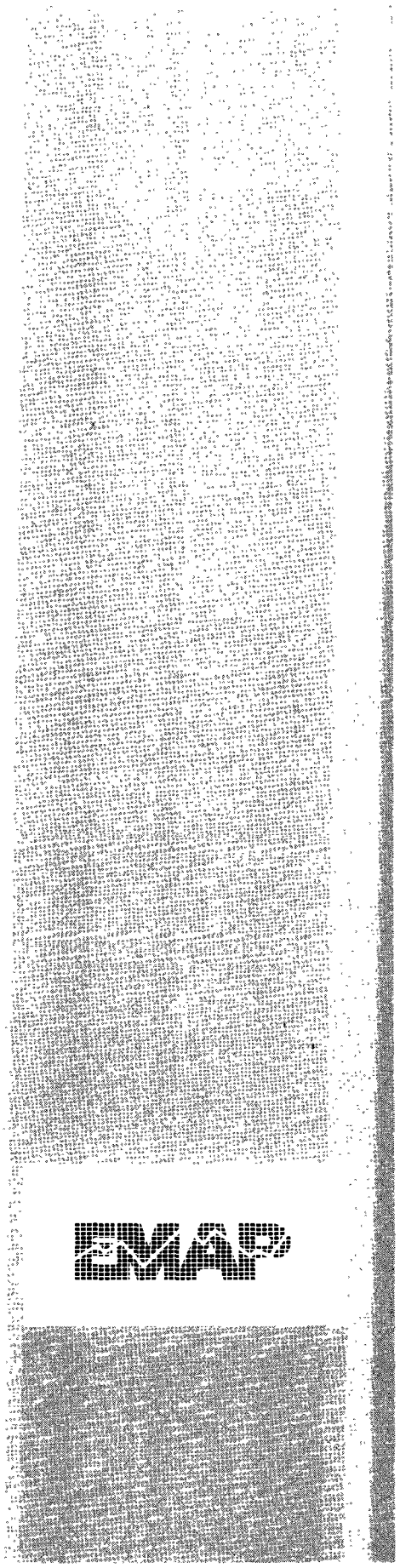

EMAP

Environmental Monitoring and Assessment Program

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ENVIRONMENTAL MONITORING AND ASSESSMENT PROGRAM: SURFACE WATERS IMPLEMENTATION PLAN - NORTHEAST PILOT LAKE SURVEY, SUMMER 1991

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ENVIRONMENTAL MONITORING AND ASSESSMENT PROGRAM: SURFACE WATERS IMPLEMENTATION PLAN - NORTHEAST PILOT LAKE SURVEY, SUMMER 1991

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ABSTRACT

This document outlines the proposed implementation plan for the Environmental Monitoring and Assessment Program's Surface Waters Northeast Lakes Pilot Survey, to be conducted from July through September, 1991. The pilot survey will evaluate not only the utility of the indicators selected thus far for the Surface Waters component, but will provide an evaluation of the methods that have been identified for collection and analysis of samples.

This implementation plan is not intended to be a step-by-step delineation of field activities planned for the pilot; for more detailed discussion of concept, approach, and issues, please refer to either the Surface Waters Research Plan (Paulsen et al., 1991) or the respective subject plans (i.e., the quality assurance project plan, the field operations manual, and the information management plan). This plan outlines the objectives of the field pilot activities and the questions which we expect to answer as a result of these activities. In addition, the plan contains a description of the indicators, the measurement variables included in each indicator, the design rationale, and details including site selection criteria and a list of selected sites. Very brief descriptions of quality assurance, logistical considerations, and the information management approach are also presented.

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ACRONYMS AND ABBREVIATIONS

AERP	Aquatic Effects Research Program
ALSC	Adirondack Lakes Survey Corporation
ANC	acid neutralizing capacity
BRC	Biologically Relevant Chemistry (Survey)
cdfs	cumulative distribution functions
chl a	chlorophyll a
DIC	dissolved inorganic carbon
DLGs	digital line graph (files)
DO	dissolved oxygen
DOC	dissolved organic carbon
EMAP	Environmental Monitoring and Assessment Program
EMAP-SW	Environmental Monitoring and Assessment Program-Surface Waters
EPA	U.S. Environmental Protection Agency
EROD	ethoxyresorufin-O-deethylase
FAX	facsimile
FY	fiscal year
GIS	Geographic Information System
GPS	Global Positioning System
ha	hectare
ID	identification
IES	Indicator Evaluation Study
IFD	Industrial Facility Discharge File
IM	Information Management
IMS	Information Management System
LESC-LV	Lockheed Engineering & Sciences Company, Las Vegas
MATC	Maximum Allowable Tissue Concentration
METI	Mantech Environmental Technologies, Incorporated
NSWS	National Surface Water Survey
PAHs	polynuclear aromatic hydrocarbons
PCA	principal component analysis
PCBs	polychlorinated biphenols
PE	performance evaluation
PDR	portable data recorder
PIRLA	Paleolimnological Investigations of Recent Lake Acidification
QA	quality assurance
QA/QC	quality assurance/quality control
QAPjP	quality assurance project plan
QC	quality control
SAS	Statistical Analysis System
SCS	Soil Conservation Service
SD	Secchi disk transparency

SWIC	Surface Waters Information Center
TAI	Technology Applications, Incorporated
TIME	Temporally Integrated Monitoring of Ecosystems
TP	total phosphorus
T1Y1	Tier 1 Year 1
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Service
VAX	Virtual Address Extension

SECTION 1
INTRODUCTION

1.1 OVERVIEW OF THE ENVIRONMENTAL MONITORING AND ASSESSMENT PROGRAM

The U.S. Environmental Protection Agency (EPA), in cooperation with other federal and state organizations, has designed the Environmental Monitoring and Assessment Program (EMAP) to periodically assess the condition of the Nation's ecological resources. The program will assist decision makers, both within and outside the Agency, to evaluate the effectiveness of current environmental regulations in protecting the Nation's natural resources, prioritize issues of concern and regions in which action is needed, and set environmental policy. EMAP is a strategy to identify and bound the extent, magnitude, and location of degradation or improvement in the environment. When EMAP has been fully implemented, the program will answer the following critical questions:

- What is the current status and extent of our ecological resources (e.g., estuaries, lakes, streams, forests, grasslands, etc.) and how are they distributed geographically?
- What percentage of resources appears to be adversely affected by pollutants or other anthropogenic environmental stresses?
- Which resources are degrading or improving, where, and at what rate?
- What are the relative magnitudes of the most likely causes of adverse effects?
- Are adversely affected ecosystems improving as expected in response to control and mitigation programs?

To answer these questions, the various, integrated monitoring networks within EMAP will focus on the following objectives:

- Estimate the current status, extent, changes, and trends in indicators of condition of the Nation's ecological resources on a regional basis with known confidence.
- Monitor indicators of pollutant exposure and habitat condition and seek associations between human-induced stresses and ecological condition that identify possible causes of adverse effects.
- Provide periodic statistical summaries and interpretive reports on ecological status and trends to the EPA Administrator and to the public.

1.2 OVERVIEW OF EMAP-SURFACE WATERS

EMAP-Surface Waters (EMAP-SW) is intended to estimate the condition of lakes, reservoirs, streams, and rivers on a national scale as well as on relatively broad, regional scales. The design of the program, which utilizes an integrated, statistical monitoring framework based on a global systematic grid, is explained in detail in Paulsen, et al., 1991. Data obtained from the program will allow estimation of the spatial extent and geographical distribution of various classes of surface waters. Additionally, the program will estimate the current status and changes or trends in indicators of ecological condition.

The EMAP-SW Resource Group uses a top-down approach to evaluate the condition of the ecosystem with respect to endpoints of concern (see Paulsen, et al., 1991). The strategy chosen for EMAP-SW employs the following attributes that will allow estimation, with known confidence, of indicators of the ecological condition of regional surface water populations:

- Precise definition of surface water target populations and associated sampling units and the selection of an explicit frame for listing or identifying all potential sampling units within each target population.

- Probability-based sample site selection from the population frame; a uniform grid and clustered sampling approach will be used to obtain a randomized, systematic sample of surface waters with a geographical distribution reflecting that of the population.

- Representation of ecological conditions in sample lakes and streams using ecological indicators employing an index concept.

- A documented set of uniform sampling and analytical methods for a suite of response, exposure, and stressor indicator measurements.

- A documented program of rigorous quality control/quality assurance (QA/QC), and assessment.

This document describes the proposed plan for implementation of the EMAP-SW Northeast Lakes Pilot Survey. The pilot, which will be conducted in the northeastern United States from July through September of 1991, will evaluate the usefulness of the indicators selected thus far. It will also evaluate the methods that have been identified for collection and analysis of samples.

SECTION 2
PILOT OBJECTIVES

2.1 OBJECTIVES OF FISCAL YEAR 1991 NORTHEAST LAKES PILOT SURVEY

Prior to full-scale implementation of EMAP-SW, a number of questions must be answered through a combination of analyses of existing data and of data derived from new field activities. We distinguish two types of field activities that we intend to undertake prior to full-scale implementation. These are pilot projects and demonstration projects. The pilot projects are intended to specifically answer questions about indicator performance, including sensitivity, components of variance for indicators, method considerations, and logistical constraints. Pilot studies are not intended to provide regional estimates of condition. A demonstration activity may be designed to answer many of the same questions outlined above, but also has as a fundamental objective the demonstration of the ability to estimate the condition of regional populations. We anticipate a combination of pilot and demonstration activities over the next three to four years before national implementation of EMAP-SW. The pilot activity described in this document will begin to answer the many questions that exist, but will not answer them all. In conjunction with well designed follow-up studies, this pilot should provide the information needed to implement the program.

2.2 QUESTIONS TO BE ANSWERED PRIOR TO FULL-SCALE IMPLEMENTATION

The basic questions which need to be answered prior to full-scale implementation of EMAP-SW are:

(1) What indicators/measurements will we use as part of the basic monitoring program?

(2) Where and when will we measure them?

(3) How will we use them to make statements about condition, associations, probable cause of impaired and unimpaired conditions, and how well can we statistically describe all of this?

The following are questions which we identified in conjunction with our Peer Review Panel as more specific questions which require answers prior to implementation of EMAP-SW:

(1) What is the magnitude of the variance components for the identified biological-response indicators which include fish, macroinvertebrates, zooplankton, sedimentary diatoms, birds, and fish pathology in a set of regional lakes?

What are the variance components for the chemical-exposure and physical habitat indicators? How does the magnitude of these components impact our ability to describe condition and trends? Components of variance which should be described include:

a. Differences among lakes within a region resulting from true differences in different lakes (true population variance).

b. Spatial and temporal differences at a lake within a given index period (index variance).

c. Differences within index samples resulting from imprecision in sample collection, sample processing, and sample analyses; and differences among index samples resulting from different teams and different laboratories (measurement variance).

d. Year-to-year site variation (annual variance).

e. Spatial correlation effects within a region.

f. Temporal correlation effects within a region.

g. Differences at a site among different index periods.

(2) A variety of habitat types exist within any particular lake and the heterogeneity of these varies between lakes. The basic question here is, how do we sample an index of the condition of the lake at a particular time for a particular indicator? For each biological-response indicator, chemical-exposure indicator, and physical-habitat indicator, a series of questions must be answered relative to habitat types.

a. How many discreet habitats need to be recognized and sampled in the regional set of lakes?

b. How much sample replication is needed for each habitat within each lake?

c. How will data from the different habitats in each lake be combined to provide a result for the whole lake to form the regional population among lakes?

d. Can a sample from a single location within the lake be used as an index of lake condition?

(3) Several questions exist concerning the logistics and variability in on-site performance of sampling teams:

a. Can teams really conduct the field sampling in the time frame described in the Surface Waters Research and Monitoring Strategy (Paulsen, et al., 1991)?

b. Can different teams be effectively trained or will the variance be so great that the program objectives will be compromised?

c. Can the field logistics be effectively monitored and controlled across a region?

(4) Concerning the ability to define trends in biological-response indicators:

a. What types of rotational sampling schemes are needed to increase sampling frequency so that trends can be discerned in reasonable time frames given the levels of variance observed for the identified biological-response indicators?

b. What test will be used for trends in population data?

c. What is the magnitude of regional trend detectable given the indicator variability and proposed design?

(5) A host of subpopulations are of concern to various clients:

a. How will critical subpopulations of interest be identified?

b. Can post-stratification really be used?

(6) Can the nominal/subnominal approach for defining conditions be made to work for each of the listed biological-response indicators?

Questions 4, 5, and 6 above can be answered independently of field pilot activities. However, answers to questions 1 to 3 require interpretation of existing data and data derived from a series of carefully designed lake pilot studies. These field activities must be followed by exhaustive data interpretation and reevaluation of the overall design and approach.

This document describes the role the Fiscal Year 1991 (FY91) field pilot will play in answering some of the critical questions outlined. This work will be complemented by extensive evaluation of existing data and computer simulation.

2.3 PILOT STUDY DESCRIPTION AND OBJECTIVES

In this section, the general description of the FY91 pilot is described along with questions which will be answered. Further details on specific indicators can be found in Section 3, while the details of site selection are addressed in Section 4.

A fundamental issue which prevented us from conducting a regional scale pilot on all indicators was our belief that we were not adequately prepared to collect an index sample of fish, littoral zone macroinvertebrates, and lake physical habitat. Thus, a key question to be answered by the pilot is: How do we obtain an index sample of fish, macroinvertebrates, and physical habitat within reasonable budgetary constraints?

Figure 2-1 shows the basic components of the field pilot for FY91. The first is a demonstration of the EMAP design for sampling lakes on a regional scale. For this component, lakes to be sampled were selected from the grid using the selection procedures described in Section 4.2. This demonstration has two subcomponents, one which begins the Temporally Integrated Monitoring of Ecosystems (TIME) program (see Section 3.2.1.2) and

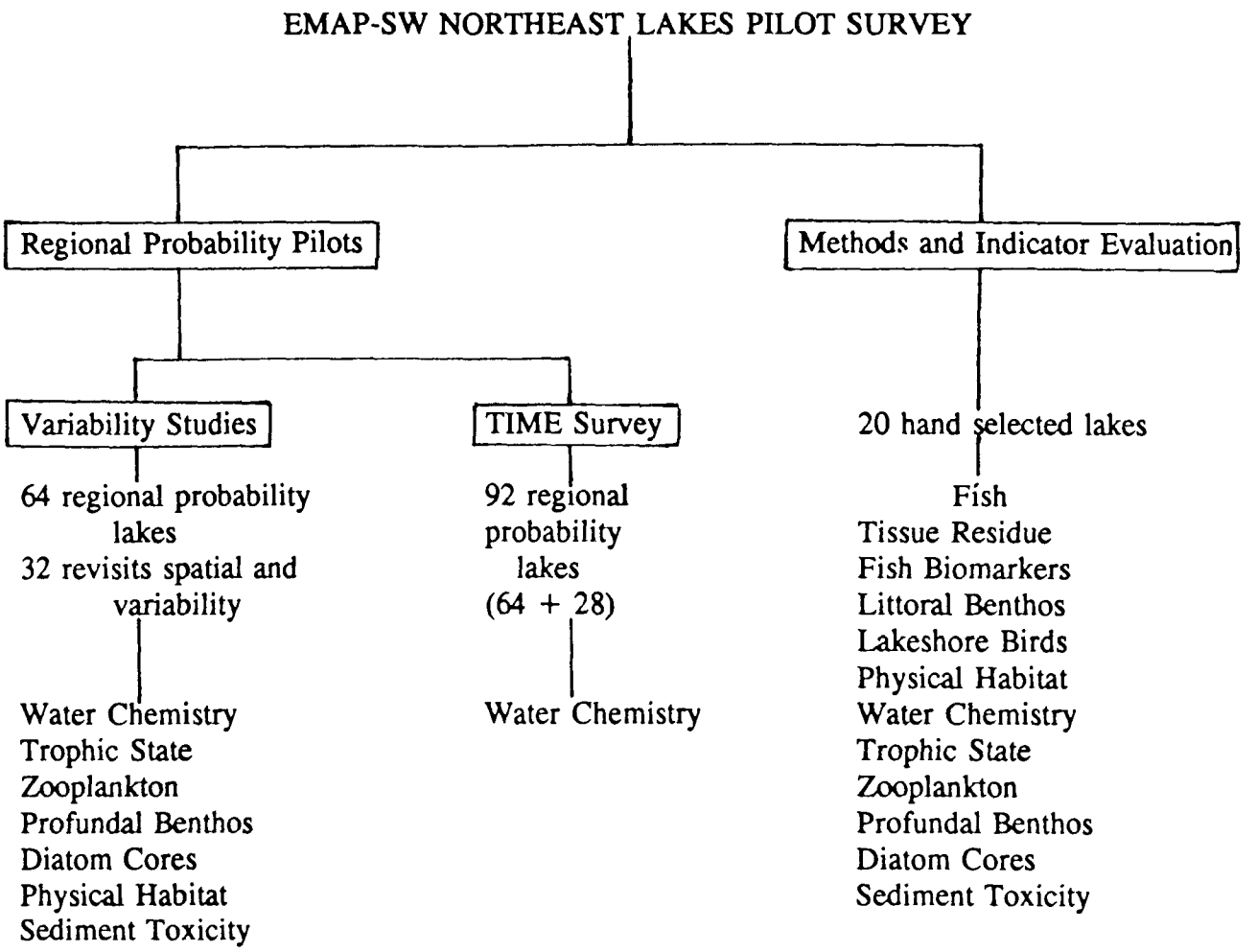

Figure 2-1. Components of the pilot activities planned for EMAP-SW during FY91.

the other in which we measure selected indicators which we believe we can effectively sample in an index mode. The difference between these two subcomponents is that the base EMAP grid has been intensified in two regions where subpopulations of lakes are especially sensitive to acidic deposition and sample sizes selected from the base grid were insufficient for trend detection. At these additional sites, only TIME indicators, primarily chemistry, will be measured.

The second component of the pilot addresses the basic question about our ability to obtain a cost effective index sample for fish, littoral macroinvertebrates, and physical habitat. During the discussions over the past year, it became evident that we would be unable to select a sampling protocol (gear, locations) with which we could obtain a sample of the fish and macroinvertebrate assemblages effectively. Thus, the primary purpose of this part of the pilot activity is to obtain sufficient information by which to select an adequate sampling protocol to be used in later surveys. To conduct this evaluation, lakes were purposely selected to cover a variety of lake sizes and types of impact to represent the range of conditions expected during routine surveys. An ancillary, though important, part of this study is an evaluation of the sensitivity of the suite of biological indicators across various impact gradients. The lake selection process is described in Section 4.4, and the specific questions to be addressed for each indicator are identified in the respective indicator subsections of Section 3.

2.3.1 Regional Probability Demonstrations

The regional probability demonstrations can be divided into two areas of concern:

a. regional variability assessment, and

b. TIME demonstration.

2.3.1.1 Regional Variability Assessment Study

For several of the proposed indicators, we believe we can adopt the index measurement concept and estimate the magnitude of regional spatial variability and within index period variability. This is best done using sites selected with known probability from the grid. Sixty-four probability sites have been selected for this study. Trophic state index, general water chemistry, zooplankton, profundal benthos, and macrophyte cover information will be collected on all of these sites. At 32 of these sites zooplankton, profundal benthos, and sediment toxicity samples will be analyzed along with cores for analyses of diatoms and chironomid headcapsules. This set of 32 lakes will be revisited during the index period to estimate index period variability. Appropriate quality assurance (QA) samples in the form of

field replicates and natural audit samples will be taken to estimate total measurement error. Detailed evaluation of components of variance that comprise measurement error will occur during FY92 field activities only if the magnitude of total measurement error is of concern. Similarly, detailed evaluation of index period variability will proceed via evaluation of existing data and additional work during FY92 if results of this year's pilot indicate index period variability to be of a magnitude which is of concern.

This population variability assessment study will estimate:

a. Regional spatial variability.

b. Index period variability.

c. Total measurement variability.

d. Regional status for selected indicators.

This field study will specifically not estimate:

a. Spatial or temporal correlation effects within a region.

b. Differences at a site between different index periods.

c. Specific estimates of the components of measurement variability.

d. Regional estimates of condition for the full suite of EMAP-SW indicators.

2.3.1.2 TIME Demonstration

As described in Paulsen et al., 1991 and Stoddard, 1990, the reauthorization of the Clean Air Act mandates an assessment of the effects of reductions in emissions on aquatic systems. The TIME project is a special program within EMAP-SW which will address the effectiveness of the changes which might result from the Clean Air Act. The regional population descriptions produced by the TIME project will result from modification of the general EMAP design. The base EMAP density will provide approximately 64 probability sites annually for use in the TIME project. Based on the results presented in Linthurst, et al. (1986), two regions of high interest (Adirondacks and southern Vermont and New Hampshire, see Figure 2-2) will not be adequately evaluated with this base density (see Paulsen, et al., 1991 and Stoddard, 1990). A three-fold increase in the grid density in these regions results in the selection of an additional 28 sites in each year of a four-year rotational cycle. Section 4 contains details of the site selection process for this project.

Indicators at the TIME sites will be primarily water chemistry-exposure indicators (e.g., pH, acid neutralizing capacity [ANC], sulfate, nitrate) intended to estimate the acidification status of these systems.

This year's TIME project will:

a. Estimate the year 1 acidification status of a variety of sensitive lake subpopulations in the Northeast. This is the first year of what is expected to be at least a 10-year period before trends which might result from changes in the Clean Air Act are expected to be detectable.

b. Evaluate the effectiveness of the design and site density in providing the needed coverage of important lake subpopulations.

2.3.2 Indicator Evaluation Study

A variety of questions exist relative to effective methods to use within EMAP-SW for the biological-response and physical habitat indicators currently under evaluation. These pertain to the gear to be used, habitats to be sampled within a lake, logistics of implementing all of the indicators, and the effectiveness of the suite of indicators when evaluated together. We are also interested in determining which indicators have information to cost ratios which might preclude future use in EMAP-SW. A set of 20 lakes has been subjectively selected to evaluate the range of lake sizes, types, and conditions that may be encountered in the Northeast. The selection process includes evaluations of existing maps, and data bases (State 305b Reports; Hocutt and Wiley, 1986; Cusimano, et al., 1990; Adirondack Lakes Survey Corporation [ALSC], 1985, 1986, 1987, 1988; Landers, et al., 1987; and Linthurst, et al., 1986), and suggestions from state biologists.

A major aspect of this portion of the pilot is evaluation of sampling gear and habitat types within a lake, and evaluation of methods for indexing fish (Hocutt and Wiley, 1986; Cusimano, et al., 1990; Adirondack Lakes Survey Corporation [ALSC], 1985, 1986, 1987, 1988; Landers, et al., 1987; and Linthurst, et al., 1986) and macroinvertebrate assemblages in lakes within EMAP-SW. For sediment toxicity, we are concerned with sample location variability, crew variability, and temporal variability (which will also be evaluated for birds). The research concerns for biomarkers center on intra- and interspecies variability. Fish tissue contamination concerns are whole fish versus filet and interspecies differences, while observer variability, index locations, and sampling effort are of concern for physical habitat.

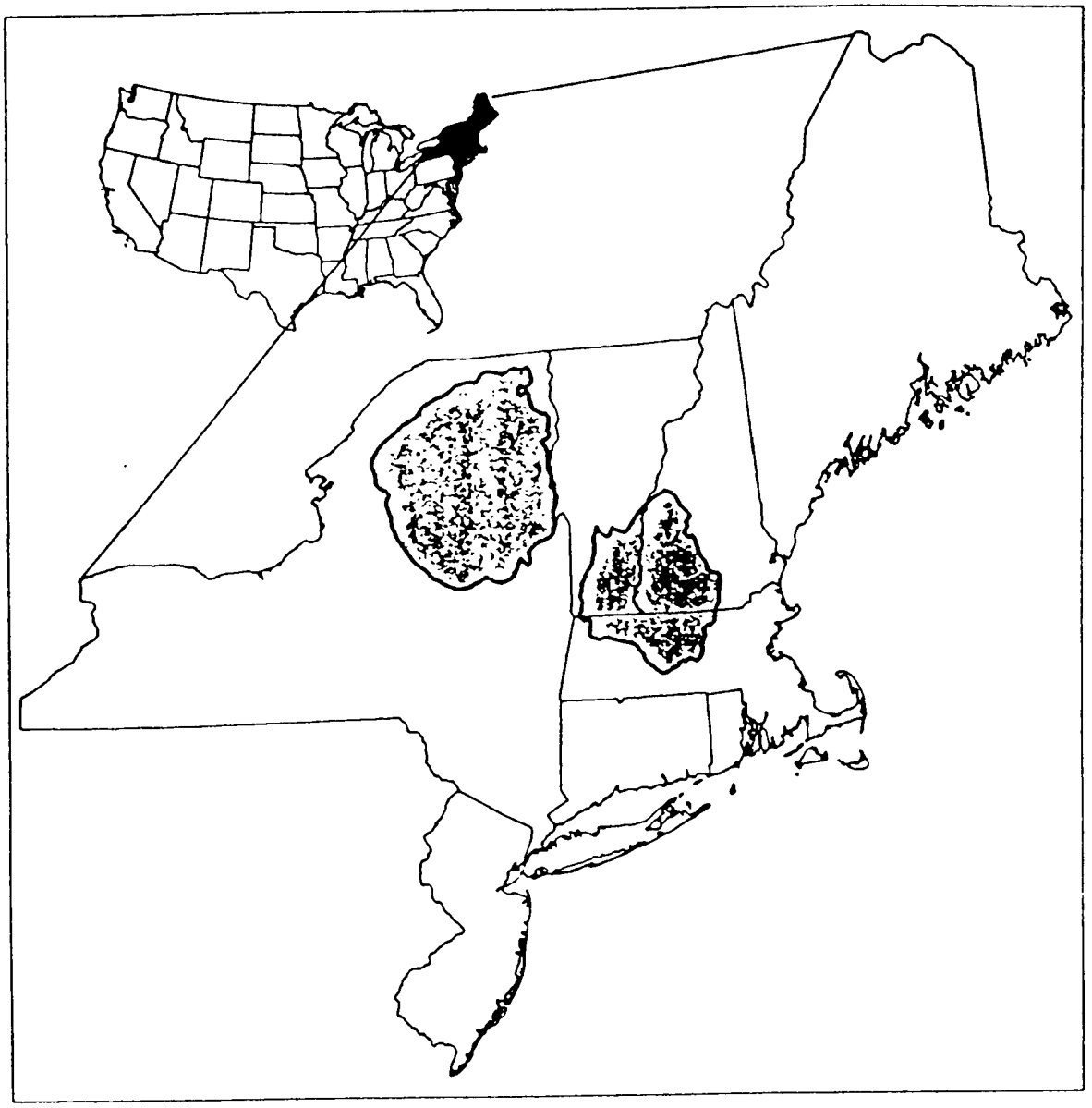

Figure 2-2. Two regions of interest for acidic deposition in which the base EMAP grid will not provide enough coverage. The grid was intensified by a factor of 3 in order to provide an additional 28 samples per year for the evaluation of acidification.

An additional aspect of this portion of the pilot is the evaluation of indicator performance over a range of natural and disturbance gradients. Because our sample size is relatively small for this activity, we will continue to include a set of subjectively selected sites for indicator performance over the course of the next several years. These sites will allow us to compare the responses of our full set of response, exposure, and habitat indicators. In addition, they provide us with the opportunity to evaluate the logistical constraints and the time necessary to implement our proposals in various types of lakes.

The indicator evaluation study (IES) will:

a. Select protocol for index sampling of the following indicators: fish, littoral benthos, physical habitat.

b. Identify major habitat types that require sampling for fish and benthos.

c. Estimate and evaluate the logistical and time requirements for implementing the complete suite of indicators in the field.

d. Begin evaluation of the suite of biological-response indicators across natural and disturbance gradients to compare their sensitivity, responsiveness, interpretability, and redundancy.

SECTION 3
INDICATORS OF ECOLOGICAL CONDITION

3.1 INTRODUCTION

In the following section, the overall objectives of the EMAP program are presented for each indicator followed by the specific pilot objective for that indicator. Following the statement of objectives for a given indicator, the methods of data collection are briefly outlined along with data analysis plans. Finally, interpretation scenarios are proposed for each indicator.

EMAP has identified four types of indicators for determining ecological condition: response, exposure, habitat, and stressor. These categories have been provided as a guideline for use in the selection, evaluation, and development of the proposed indicators for EMAP-SW.

- **Response indicators** are attributes that quantify the integrated response of ecological resources to individual or multiple stressors. Examples of this kind of indicator include fish assemblage, diatom assemblage, and macroinvertebrate assemblage.

- **Exposure indicators** are physical, chemical, and biological attributes that can be used to suggest pollutant exposure and assist in the diagnosis of probable cause. In addition, exposure indicators are extremely critical for assessing water body types and expected conditions for aquatic systems. Examples of exposure indicators are sediment toxicity, chemical contaminants in fish, and ambient nutrient concentration.

- **Habitat indicators** are attributes that describe the condition of the environment. They are used to suggest whether alteration or disturbance of the physical habitat is the cause of poor condition in response indicators. Examples of this type of indicator are surface area, lake level, or hydrologic residence time.

- **Stressor indicators** are economic, social, or engineering attributes that are used to identify the most probable sources of environmental impairment or exposure to impact. Some examples of this indicator type are human population density, land-use patterns, pesticide application rates, point-source pollutant loadings, and stocking and harvest records.

Table 3-1 provides a list of indicator measurements (grouped by indicator type) proposed for the Northeast Lakes Pilot. Each indicator is described in detail in the following sections.

TABLE 3-1. INDICATOR MEASUREMENTS PROPOSED FOR THE 1991 EMAP-SW NORTHEAST LAKES PILOT SURVEY

Response Indicators	Habitat Indicators
Trophic State	Physical Habitat Quality
Sediment Diatom Assemblage	
Benthic Macroinvertebrate Assemblage	Stressor Indicators
Zooplankton Assemblage	Land Use
Fish Assemblage	Landscape Cover
Riparian Bird Assemblage	Human Population Density
	Fish Management Practices
Exposure Indicators	Transportation
Sediment Toxicity	
Fish Biomarkers	
Fish Tissue Contaminants	
Fish External Anomalies	
Water Chemistry	

3.2 TROPHIC STATE

3.2.1 Overall Objectives

The overall objective of this indicator is to estimate the proportion of lakes that are in various trophic categories (oligotrophic, mesotrophic, eutrophic, dystrophic) based primarily on measurements of total phosphorus (TP), chlorophyll a (chl a), and Secchi disk transparency (SD).

3.2.2 Objectives of the Pilot

- Estimate the magnitude of spatial variability in the Northeast.
- Estimate the magnitude of variation associated with the sampling index window, especially relative to population variation of lakes in the Northeast.
- Evaluate associations between the trophic indicators and sediment diatoms, zooplankton, benthos, and fish assemblages.

3.2.3 Data Collection and Analysis

Chlorophyll a, TP, and SD will be taken at a spot that approximates the deepest part of the lake, in the epilimnion (1.5m below the surface, or a clean sample for shallow lakes).

One important question to be answered in the pilot for the Northeast will be: "How large is index variation relative to population (regional) variation, and how large is index variation relative to variation of selected subpopulations?" Our variance models, simulations, and summaries of variance indicate that it will be necessary to measure both spatial and temporal components of index variation as part of the basic sampling design.

The basic trophic state measurements will be combined into an index such as Carlson's trophic state index (Carlson, 1977). This index is constructed on the basis of SD and its correlation with chl a and TP. The index runs from 0 to more than 100, but operationally, values generally occur from 30 to 49 or from 80 to 90. The larger the value, the more productive the system. Each change of 10 on the index corresponds to halving of SD and doubling of TP. Although cumulative distribution functions (cdfs) of the index can be reported, it might also be appropriate to report cdfs of the individual measurements.

3.3 SEDIMENTARY DIATOM ASSEMBLAGE

3.3.1 Overall Objectives

- Estimate the proportion of lakes that are in various trophic categories.
- Estimate the proportion of lakes that were in various trophic categories prior to major anthropogenic impact.
- Estimate the rate of environmental change (as these data accumulate over time).

3.3.2 Objectives of the Pilot

- To calibrate sediment surface diatom assemblages to the following environmental variables:

  pH
  alkalinity
  monomeric and total aluminum
  dissolved organic carbon
  salinity

conductivity
total nitrogen
TP
calcium
SD
chl a

NOTE: pH has been calibrated, but it will be informative to compare the model derived from a probability sample with existing models).

- To develop predictive models for inferring lake conditions.

- To estimate spatial variability.

- To evaluate and document the total method, including:

  field methods
  coring procedures
  core sampling and archiving
  laboratory methods
  diatom analysis
  diatom QA
  sediment dating
  statistical methods
  data base development
  ordination techniques
  Monte Carlo simulation
  bootstrapping

3.3.3 Data Collection and Analysis

Sediment core samples will be collected from the deepest part of each lake. The upper 1cm of sediment and 1cm of sediment from the bottom of the core will be collected and preserved for laboratory analysis of the diatom communities. Because funds are sufficient this year for analyzing only 64 cores, the focus will be on the 20 indicator lakes and 44 of the EMAP-TIME lakes, which will be chosen to provide a wide range of conditions. Cores from the remaining lakes will be examined the following year.

Methods for diatom research have been evaluated and standardized for three large, multi-institution paleolimnological research projects which investigated the effects of acid rain on aquatic resources in the United States (Paleolimnological Investigations of Recent Lake Acidification [PIRLA]-I, Charles and Whitehead, 1986; PIRLA-II, Charles and Smol,

1990), and the Surface Water Acidification Programme of Great Britain and Scandinavia (Battarbee et al., 1990). Details of the methods to be used in this study may be found in the EMAP-SW Pilot Field Operations and Training Manual (Tallent-Halsell and Merritt, in preparation).

3.4 MACROINVERTEBRATE ASSEMBLAGE

3.4.1 Overall Objectives

- Develop and measure quantifiable indices of lake condition based on invertebrate assemblages.
- Monitor the condition of lakes using invertebrate assemblage information.

3.4.2 Objectives of the Pilot

- Collect profundal benthos and sediment core samples for determination of the profundal benthic assemblages (regional variability study).
- Develop efficient sampling methods for littoral benthic invertebrate communities (IES).
- Determine regional spatial variability.
- Determine index period variability.

3.4.3 Data Collection and Analysis

Profundal samples will be collected from the deepest part of the lake using a stainless steel, petite PONAR dredge. Samples will be sieved in the field, preserved, and transported for laboratory analysis of the benthic invertebrate community. Sediment core samples will be collected from the same area of each lake. The upper 1 cm of sediment and 1 cm of sediment from the bottom of the core will be collected and preserved for laboratory analysis of chironomid head capsules and Chaoborus mandible remains. This will be the same core sample used for diatom assemblage analysis (see Section 3.4.2). Littoral benthic samples will be collected along with inflow and outflow samples using a combination of sweep net, rock picking, vegetation washing, and kick sampling. The goal is to determine the optimal combination of sampling methods for definition of overall lake benthic assemblage composition.

3.5 ZOOPLANKTON

3.5.1 Overall Objectives

- Develop and refine zooplankton indices based on established ecological principles which measure lake trophic condition.
- Define the concept of biological integrity using zooplankton assemblage data.
- Elucidate community patterns consistent with other indices to define a metric for this endpoint.
- Develop techniques for detecting changes in zooplankton community structure by classes of lakes and at regional scales.
- Classify lake health or condition according to zooplankton community assemblages and portray their biogeographical landscape.

3.5.2 Objectives of the Pilot

- Collect, process, and analyze the pilot data set emphasizing community differences among classes of lakes which are known to differ greatly in anthropogenic stress factors.
- Use these data and the zooplankton data subset to develop zooplankton indicators and metrics for the three major endpoints (trophic state, biotic integrity, and fishability).
- Define objectives of regional spatial variability and index period variability.

3.5.3 Data Collection and Analysis

One vertical tow from one meter off the bottom to the surface will be collected at the deepest part of the lake using two nets mounted on a 2-ring "bongo" harness designed to collect a stratified sample (202 μm and 48 μm Nitex mesh). Two samples will be collected simultaneously, giving unbiased macro- and microzooplankton fractions. For the pilot study, we will evaluate what advantage, if any, quantitative counts provide over relative counts, and this information will be used to reduce processing efforts in the future. Similarly, zooplankton will be identified to the lowest taxonomic level possible using current keys. The degree of taxonomic resolution needed to meet EMAP-SW goals will be assessed and incorporated in future EMAP analyses. Reference slides for each crustacean taxon will be made, and reference photographs and measurements taken for rotifers.

Principal component analysis (PCA) will be done to identify the primary structure of the data set. This analysis will provide classes of lakes defined by their zooplankton communities. Using PCA lake groupings, the underlying species structure defining these lake groups will be studied in more detail. At this point, preliminary indices can be derived, as well as development of metrics for EMAP-SW applications. These metrics will eventually be correlated and supported with other independent variables making up the EMAP-SW data base such as fish community structure, lake trophic state, and physical and chemical habitat quality.

3.6 FISH ASSEMBLAGE

3.6.1 Overall Objectives

- Develop and measure quantifiable indices of lake ecological condition based on fish assemblages.
- Monitor the ecological condition of lakes using fish assemblage information.
- Develop and measure indices of the fishability of lakes.
- Monitor the fishability of lakes.

3.6.2 Objectives of the Pilot

- Determine fish species presence and proportional abundance in individual lakes over a range of natural and impacted conditions.
- Provide sample materials for evaluation of fish tissue contaminants and biomarkers.
- Evaluate the variability and effectiveness of five commonly used fish sampling methods, applied at a variety of habitats and with progressive degrees of effort.
- Determine optimal sampling methods for lake fish and the effort required to perform index sampling, for use in a national scale monitoring program.
- Evaluate the effectiveness of a rapid (field) zooplankton assessment for determining the presence of a planktivorous fish assemblage.

3.6.3 Data Collection and Analysis

Fish will be collected with passive gear (overnight sets of Swedish experimental gill nets [five mesh sizes], Indiana trap nets, minnow traps, and eel pots [in Atlantic drainage

lakes]; and by active methods after sunset [i.e., electrofishing in littoral areas, beach seines, and short haul seines in areas of cover]). Gear will be set and active sampling will be done in habitat types where fish are expected and at a set of systematically selected sites. Sampling will require two or three days at each lake, depending on lake size and complexity. Up to five sets of each passive gear type will be placed, (up to three sites for eel pots). Five sites will be seined and electrofished in smaller lakes (<20 ha). In larger lakes, this effort will be doubled (with a maximum of three sites for eel pots). Fish collected will be identified to species and size class (young-of-year, juvenile, and adult) in the field, and examined for external gross pathology. All fish data will be recorded by the specific gear/method used and by the location (habitat type) to assess the relative effectiveness of the various sampling methods and collection locations. Voucher specimens will be preserved and placed with the Harvard Museum of Zoology for taxonomic confirmation and curation.

At four small, warm-water lakes chosen over a range of expected industrial and agricultural impacts, up to ten fish each of four species will be preserved on dry ice and shipped for laboratory analyses of potential tissue contaminants (Section 3.9). At all four lakes, blood, gill and liver samples will be collected from up to ten live fish (each of two species), preserved in a liquid nitrogen freezer or dry ice, and shipped for laboratory analysis of biomarkers (Section 3.10).

Optimal allocation of sampling effort is important to the efficient operation of regional scale surveys. As sampling effort increases, the probability of error in assessment of fish species presence/absence becomes asymptotic (EA Science and Technology, 1986). The pilot data will be assessed both by individual gear/method and in combination to determine an appropriate level of effort (for an acceptable level of error) for a range of lake sizes and lake types. It is important for future lake sampling in EMAP-SW to know the minimum effort (labor, time, and equipment) needed to get an adequate index sample of fish assemblages.

Ordinations (Detrended Correspondence Analysis and Canonical Correspondence Analysis) will be used to examine the species assemblage structure, identify lakes with similar species assemblages, and assess the relationships of the species to components of the physical environment. Although the number of lakes sampled for fish in the pilot is small, we can begin to develop indices and metrics for EMAP-SW applications from these data, especially from the minimally-impacted reference lakes. For example, a species richness model based on waterbody size and type has potential as a regional-scale indicator of ecological condition (Whittier and Rankin, 1991), and can also be used as one component of a multimetric index.

Fish assemblage data will also be used to assess the fishability endpoint of concern. The occurrence and size of game fish species will determine the potential for a sports fishery. The presence of external anomalies and/or tissue contaminants will partially address

the quality and sustainability of the fishery. It may not be possible to develop a single fishability index because of the subjective nature of this endpoint. Initially, we will probably report on several indices, such as the proportion of lakes with game species of catchable size, proportion of game species with anomalies and/or consumption criteria violations due to contaminants, and proportion of lakes requiring stocking programs to maintain a sports fishery.

3.7 RIPARIAN BIRD ASSEMBLAGE

3.7.1 Overall Objectives

- Develop an indicator that represents the riparian zone to link the aquatic ecosystem with certain terrestrial sources of disturbance.

- Test the sensitivity and cost-effectiveness of birds as indicators of ecosystem condition relative to other indicators.

- Develop an index that uses bird assemblage information to characterize lake and riparian condition.

3.7.2 Objectives of the Pilot

- Evaluate sampling methods, index period, index location, and measurement variability at a set of twenty lakes of varying size, type, and degree of disturbance.

- Determine which bird species and which guild combinations provide the best information about ecosystem condition.

- Correlate avian guild rankings of sensitive and tolerant taxa, trophic groups, wetland dependent species, and habitat specialists with the range of conditions represented at the sampled lakes.

3.7.3 Data Collection and Analysis

The EMAP-SW Riparian Bird survey will be conducted by cooperators from the University of Maine. Two teams of two ornithologists each will visit the 20 lakes twice to complete a 40-lake sample. The index sampling period is from May 30 to July 3, 1991. At each lake, the field crew will canoe a transect, stopping every 200m to record birds seen or heard within a five-minute period. This point-count method is appropriate for estimating bird community composition in patchy habitats (Reynolds, et al., 1980). The field crew will also record habitat information. The recording of sightings and habitat information will follow

the guidelines established for Breeding Bird Survey participants by the U.S. Fish and Wildlife Service [USFWS] (USFWS, 1990).

The bird survey data from the twenty reference and impacted lakes will be used to develop a preliminary index that reflects the cumulative disturbance of lakeshore habitats. The metrics that compose the index will be derived from rankings of species trophic status, habitat specificity, wetland dependency, etc.

3.8 SEDIMENT TOXICITY

3.8.1 Overall Objectives

- Estimate the proportion of lakes that have toxic bottom sediments.
- Estimate what proportion of lakes with toxic bottom sediments are toxic due to conventional pollutants (i.e., not priority pollutants, low dissolved oxygen (DO), or ammonia toxicity).
- Estimate the proportion of lakes that have toxic bottom sediments and fish tissue contamination.
- Estimate the proportion of each trophic category that have toxic bottom sediments due to conventional or non-conventional pollutants.

3.8.2 Objectives of the Pilot

- Estimate regional spatial variability.
- Evaluate acute and short-term chronic test endpoints and their relationship to fish tissue contamination and trophic state, and conventional/non-conventional pollutants levels (DO and ammonia levels).
- Evaluate whether profundal zone sediments can be used to estimate the proportion of lakes with toxic bottom sediments.

3.8.3 Data Collection and Analysis

Three liters of profundal sediment will be collected from the deepest part of the 32 TIME/EMAP-SW lakes using a stainless steel petite PONAR dredge sampler. In addition, 4 of the 20 indicator testing lakes will be sampled. Samples will be composited and kept on ice until received by the testing laboratory, then refrigerated. Whole sediment samples will be used for 7-day testing with the epibenthic amphipod Hyallela azteca. Two-day old (+ 1

day) amphipods will be placed in test containers with 100 mls of sediment and 400 mls of moderately hard, reconstituted water. Four replicate test chambers with 20 amphipods will be used for each profundal sediment collected. A performance control sediment (known to be non-toxic) will also be used for each batch of lake samples tested. Each day for six days, overlying reconstituted water will be replaced. Prior to replacement, DO, conductance, ammonia, temperature, and pH will be measured in the overlying water. Alkalinity and hardness will be analyzed in the overlying water at the end of day 1, day 4, and day 7 of the test.

At the end of seven days, amphipods will be recovered from each replicate sample, counted, and dried at 60 °C for 24 hours. Both survival and dry weight will be used to estimate acute or short-term chronic toxicity. On a small number of lakes, samples collected from two littoral zones where macrobenthos have been collected will also be tested in this manner.

Mortality and short-term growth of amphipods will be compared to the performance control sediment and sediments taken from known near-pristine lakes (reference control sediments). Statistical differences between performance control sediments and/or reference control sediments will be used to evaluate between- and within-lake differences in toxicity. Statistical difference alone will not be the determinant for toxicity. In order to address ecological relevance, other indicators such as macrobenthos will be used to establish ecologically significant toxic sediments.

3.9 CHEMICAL CONTAMINANTS IN FISH

3.9.1 Overall Objectives

This is one of the indicators that will be used to assess the fishability endpoint. Fishability can be described simplistically by the following three questions:

(1) Are there game fish in the system?
(2) Can I catch them?
(3) Can I eat what I catch?

By measuring the level of known toxic chemicals in the tissue of game species from the systems of interest, we can answer the third question above.

3.9.2 Objectives of the Pilot

Due to the very small number of lakes in the 20-lake portion of the pilot likely to be impacted by chemical contaminants, there will be no attempt to assess the spatial variability of this indicator in the pilot. However, if some contaminated lakes are included in the study,

and sufficient fish are collected at each of the lakes of interest, sufficient information should be generated to meet the following objectives:

- Evaluation of the effects of trophic level differences on tissue contaminant levels.
- Evaluation of the effects of species differences within a trophic level on tissue contaminant levels.
- Evaluation of the effects of assaying samples of whole fish homogenates versus filet-only homogenates on tissue contaminant levels.

3.9.3 Data Collection and Analysis

A detailed description of the data collection and analysis procedures for this indicator is included in the EMAP-SW Laboratory Methods Manual (Klemm, in preparation). Briefly, 10 fish from each of 4 target species will be collected in 4 of the 20 research lakes. These lakes include an unimpacted reference lake and three lakes with known or potential chemical contamination. Target species will include two top carnivores/game species (bass and/or bluegill and/or yellow perch), and two species of bottom feeders (brown bullhead catfish and/or white sucker and/or common carp). Final selection of the target species will be determined once the 20-lake set is chosen. For each of the target species, primary and secondary size ranges will be developed to ensure selection of adult fish at or above the legal limit for that location. Use of minimum and maximum values to define the primary size range will help reduce variability within a composite sample.

For each set of ten fish of a given species, five fish will be gutted in the field and frozen on dry ice, while the remaining five fish will be frozen whole. All of the fish will then be shipped on dry ice to a laboratory for analysis. Sections of the filet portion from each of the gutted fish will be removed from the carcass, and the five filet sections for that species from that lake will be homogenized together to obtain a composite filet sample. The remaining five fish for a given target species and lake will be combined and homogenized in order to obtain a composite whole fish sample. Each composite sample will then be analyzed for the analytes given in Table 3-2 according to protocols described in the Surface Waters Methods Manual (Klemm, in preparation) and data compared to the maximum allowable tissue concentrations as defined by the EPA Office of Water (Table 3-3).

TABLE 3-2. ANALYTES TO BE MEASURED IN FISH TISSUE FOR THE 1991 EMAP-SW NORTHEAST LAKES PILOT SURVEY

Analyte (CAS[a] Number)	Detection Limits (ppm)
Aldrin (309-00-2)	0.00025
Aluminum (7429-90-5)	10.0
Arsenic (7440-38-2)	2.0
Cadmium (7440-43-9)	0.2
Chlordane-cis (5103-71-9)	0.00025
Chromium (7440-47-3)	0.1
Copper (7440-50-8)	5.0
2,4'-DDD (53-19-0)	0.00025
4,4'-DDD (72-54-8)	0.00025
2,4'-DDE (3424-82-6)	0.00025
4,4'-DDE (72-55-9)	0.00025
2,4'-DDT (789-02-6)	0.00025
4,4'-DDT (50-29-3)	0.00025
Dieldrin (60-57-1)	0.00025
Endrin (72-20-8)	0.00025
Heptachlor (76-44-8)	0.00025
Heptachlor Epoxide (1024-57-3)	0.00025
Hexachlorobenzene (118-74-1)	0.00025
Hexachlorocyclohexane [Gamma-BHC/Lindane] (58-89-9)	0.00025
Iron (7439-89-6)	50.0
Lead (7439-92-1)	0.1
Mercury (7439-97-6)	0.01
Mirex (2385-85-5)	0.00025
Nickel (7440-02-0)	0.5
trans-Nonachlor (3765-80-5)	0.00025
PCB Isomers	
2,4-Dichlorobiphenyl (34883-43-7)	0.001
2,2',5-Trichlorobiphenyl (37680-65-2)	0.001
2,4,4'-Trichlorobiphenyl (7012-37-5)	0.001
2,2',5,5'-Tetrachlorobiphenyl (35693-99-3)	0.001
2,2',3,5'-Tetrachlorobiphenyl	0.001
2,3',4,4'-Tetrachlorobiphenyl	0.001
2,2',4,5,5'-Pentachlorobiphenyl (37680-73-2)	0.001
2,3',4,4',5-Pentachlorobiphenyl (31508-00-6)	0.001
2,2',4,4',5,5'-Hexachlorobiphenyl (35065-27-1)	0.001
2,3,3',4,4'-Pentachlorobiphenyl	0.001
2,2',3,4,4',5-Hexachlorobiphenyl (35065-28-2)	0.001
2,2',3,4',5,5',6-Heptachlorobiphenyl (52663-68-0)	0.001
2,2',3,3',4,4'-Hexachlorobiphenyl (38380-07-3)	0.001
2,2',3,4,4',5,5'-Heptachlorobiphenyl (35065-29-3)	0.001
2,2',3,3',4,4',5-Heptachlorobiphenyl (35065-30-6)	0.001
2,2',3,3',4,4',5,6-Octachlorobiphenyl (52663-78-2)	0.001
2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl (40186-72-9)	0.001
Decachlorobiphenyl (2051-24-3)	0.001
Silica [Silicon] (7631-86-9)	1.0
Silver (7440-22-4)	0.01
Tin (7440-31-5)	0.05
Zinc (7440-66-6)	50.0

[a] Chemical Abstracts Service registry number.

TABLE 3-3. MAXIMUM ALLOWABLE TISSUE CONCENTRATIONS FOR FISH TISSUE CONTAMINANTS

Analyte (CAS Number)	MATC[a] (ppm)
Aldrin (309-00-2)	0.00036893
Aluminum (7429-90-5)	
Arsenic (7440-38-2)	0.00077
Cadmium (7440-43-9)	
Chlordane-cis (5103-71-9)	0.006768
Chromium (7440-47-3)	
Copper (7440-50-8)	
2,4'-DDD (53-19-0)	
4,4'-DDD (72-54-8)	0.0012864
2,4'-DDE (3424-82-6)	0.0012864
4,4'-DDE (72-55-9)	0.0012864
2,4'-DDT (789-02-6)	0.0012864
4,4'-DDT (50-29-3)	0.0012864
Dieldrin (60-57-1)	0.00035492
Endrin (72-20-8)	
Heptachlor (76-44-8)	0.004553
Heptachlor Epoxide (1024-57-3)	0.004176
Hexachlorobenzene (118-74-1)	0.0066304
Hexachlorocyclohexane [Gamma-BHC/Lindane] (58-89-9)	0.008125
Iron (7439-89-6)	
Lead (7439-92-1)	
Mercury (7439-97-6)	0.803
Mirex (2385-85-5)	
Nickel (7440-02-0)	4.7
trans-Nonachlor (3765-80-5)	
PCB Isomers	0.0024648[b]
Silica [Silicon] (7631-86-9)	
Silver (7440-22-4)	
Tin (7440-31-5)	
Zinc (7440-66-6)	

[a] MATC =Maximum Allowable Tissue Concentration, based on EPA Office of Water Human Health Criteria and Bioconcentration Factors (09/09/88).

[b] MATC for Arochlor 1221, 1232, 1248, 1260, and 1016.

3.10 BIOMARKERS

3.10.1 Overall Objectives

- Determine the percentage of lakes possessing "healthy" wildlife based on a set of biochemical and physiological measurements that are altered by exposure to toxicants and habitat stressors.

3.10.2 Objectives of the Pilot

- Evaluate a set of biomarkers in fish for their practicality for field use.

- Establish response patterns and baselines for two to five species of fish in order to permit interlake comparisons.

- Evaluate correlations of biomarkers with other indicators including external anomalies, analytical chemistry, toxicity tests, fish assemblages, and other indicators.

3.10.3 Data Collection and Analysis

Fish will be collected by electrofishing, traps, and seines. A total of twenty fish composed of two species will be selected per sample. Blood will be drawn and plasma frozen for analysis of cholinesterase, albumin, total and direct bilirubin, creatinine, total protein, blood urea nitrogen, triglycerides, cholesterol, aspartate amino transferase, alanine amino transferase, alkaline phosphatase, and lactate dehydrogenase. Liver will be excised and frozen for later measurement of ethoxyresorufin-O-deethylase (EROD) activities, glutathione, and cytochrome C reductase. Gill tissue will be frozen for identification and semiquantitation of a 70 K dalton stress protein.

Markers will be evaluated, individually and as a group. Discriminant analysis will be used to characterize the lakes according to fish health in relation to toxicant levels and habitat alteration.

3.11 PHYSICAL HABITAT QUALITY

3.11.1 Overall Objectives

- Develop and measure quantitative, reproducible indices that:

    a. describe biologically relevant aspects of lake morphometry, hydrology, and shoreline characteristics;

    b. can be used to classify lakes on the basis of physical habitat and monitor change through time.

3.11.2 Objectives of the Pilot

- Fix definitions and approaches for measuring indices of lake size, lake persistence, and lake physical habitat complexity.

- Identify a minimum subset of within-lake habitat types that are necessary sampling strata for EMAP-SW biotic response variables under current and possible future conditions of habitat quality.

- Refine the definition and methods for quantifying the extent and characteristics of the minimum set of biologically important habitat types.

- Quantify the precision of physical habitat indicator measurements (i.e., lake size and persistence, physical habitat complexity, and extent of habitat types within lakes).

3.11.3 Data Collection and Analysis

Data collection activities for describing and quantifying lake physical habitat will involve both map/photo examination and field data collection. Measurements are organized into three categories leading to indices of: (1) lake size and persistence; (2) lake habitat complexity; and (3) shoreline characteristics. Field, map, and aerial photo data will contribute to all three of these major indices (Table 3-4). Field data will be obtained by crews in boats making observations at systematically spaced near-shore locations around the lake. Data will be both quantitative (e.g., bathymetry and position-location) and semiquantitative (e.g., ranking of habitat types, aerial estimates of aquatic macrophyte cover, and determination of presence-absence of habitat features). Observers will rank shoreline vegetation and substrate types and will identify the presence of fish cover and evidence of human influences. They will also describe bank steepness and apparent lake level changes, and will estimate aquatic macrophyte coverage in the littoral areas.

In the 20-lake indicator testing study, the lake shoreline/littoral habitat and lake bathymetry surveys will both be undertaken. Replicate measurements of shoreline/littoral habitat by separate crews in the 20-lake study will allow a comparison of field measurement variability with the range of physical habitat differences encountered across gradients of anthropogenic impact.

Systematic shoreline/littoral observations at very dense site spacings in 4 to 7 of the 20 indicator testing lakes will allow estimates of variation in measurements that result from spatial placement of the shoreline observation points. Interpretation of the sources of variation in these physical habitat surveys will allow a refinement of the systematic procedures and, if necessary, an adjustment of sampling effort necessary in the rapid assessments.

In addition to conducting traditional sonar surveys in the 20-lake indicator development lakes, crews will attempt to develop rapid sonar survey procedures for obtaining bathymetric information sufficient for estimating littoral dominance, calculating lake and littoral volume, and locating sites for fish and macroinvertebrate sampling. Bathymetric

TABLE 3-4. LAKE PHYSICAL HABITAT INDICES TO BE TESTED FOR EMAP-SW

Variable	Protocol
Lake Size and Persistence Index Components	
Lake Surface Area	Determined by planimetry on 1:24,000-scale maps. Where available, mapped lake areas will be compared with those measured from recent aerial photographs.
Maximum Lake Depth	Measured in field by crew judgement of deepest location. Compare results with those from bathymetric map and/or sonar survey.
Lake Level Fluctuation	Measure and calculate percent changes in lake maximum depth and lake surface area from field shoreline surveys. Field crews estimate typical annual depth variation by examining shoreline vegetation and watermarks to determine (using rod and clinometer) the "typical" annual difference between high and low water levels. Useful non-dimensional ratio is [annual depth difference]/[maximum depth]. For percentage change in lake area, field crews examine shoreline vegetation and watermarks in several locations to estimate and then roughly map the "typical" annual difference between shoreline location at low and high water -- assumes late summer sample time is a good surrogate for the lowest water level; this is not perfect for all regions.
Lake Residence Time	Tr = [Est. volume]/[Runoff * Topographic watershed area], where volume is estimated from bathymetric maps or known documents, runoff is from runoff maps, and topographic watershed area is determined by planimetry from boundaries drawn on 1:24,000 scale U.S. Geological Service (USGS) maps.
Lake Habitat Complexity Index Components	
Littoral Dominance	Indices under consideration are the percentages of the lake area with aquatic macrophyte beds, the percentage with depth less than some named value (e.g., 3 m), or the percentage with depth less than the measured Secchi depth.
Bottom Habitat Complexity	We propose that field crews criss-cross each lake with 5 to 7 transects recording depth with a recording analog sonar "fish finder." A bathymetric map is constructed from this data using a contouring program. The coefficient of lake depth variation from a "smooth" bottom curve along a transect of lake depth will be used to obtain an additional index of lake bottom complexity.
Shoreline Complexity	Shoreline development (DL) will be indexed as: DL = L/[2(_A)0.5],where L is mapped shoreline length from planimetry, and A is the lake surface area. DL relates the deviation of the lake shoreline from a perfect circle. An alternate index under development is measured by evaluating characteristic sizes of shoreline indentations over a range of spatial scales by examining aerial photographs and field data with "box filling" algorithms (Loehle, in press). This approach calculates the change in the fractal dimension of lake shoreline length with increasing spatial scale (from meters to kilometers).
Lake Shoreline Characterization	
Shoreline Littoral Habitat	Shoreline/littoral habitat frequency and distribution of shoreline fish concealment, littoral substrate size, emergent, submergent and floating macrophytes, based on systematic field observations.
Near Shore Habitat	Percent and distribution of near-shore terrestrial/wetland habitat in various habitat classes based on systematic field observations supplemented by maps and aerial photos. Potential classes include: urban, industrial, forest, shrub, grassland, row crops, barren, wetland.

descriptions from these rapid procedures will be compared with more time-intensive traditional methods to evaluate whether or not detailed bathymetry is needed for full-scale EMAP-SW implementation.

3.12 CHEMICAL HABITAT QUALITY

3.12.1 Overall Objectives

- Develop and measure quantifiable, reproducible indices that describe the chemical characteristics of lakes that influence biota.
- Monitor the change in acid-base status in acid-sensitive regions of the U.S. (EMAP-TIME).

3.12.2 Objectives of the Pilot

- Collect first year of data for evaluating trends in acid-base status as mandated in the revised Clean Air Act.
- Develop classification of lakewater chemical types.
- Assess the within index period variability in chemical habitat indicators.
- Assess regional within index period variability.
- Assess regional spatial variability.

3.12.3 Data Collection and Analysis

Water samples for lake characterization will be collected from a depth of 1.5 m at the deepest point in the lake. Variables to be measured are presented in Table 3-2 and analytical protocols are discussed in the laboratory methods manual (Klemm, in preparation). Specific analytical methodologies for almost all of these variables will be taken from the Aquatic Effects Research Program (AERP) laboratory methods handbook (U.S. EPA, 1987). A subset (one-third to one-half) of the pilot lakes will be analyzed at two different times during the pilot survey index period to assess within index period chemical variability. Existing data bases will be used to evaluate between-season variability. Field replicate samples and natural performance evaluation samples will also be analyzed to quantify the sampling precision, accuracy, and bias.

TABLE 3-5. CHEMICAL HABITAT MEASUREMENT VARIABLES

Temperature	Dissolved oxygen (DO)
Transparency	Conductivity
Total suspended solids (unfiltered)	Ash-free suspended solids (unfiltered)
pH (field)	pH (closed)
pH (equilibrated)	Acid neutralizing capacity (ANC) - Gran
Dissolved inorganic carbon (DIC) - air equilibrated)	Dissolved organic carbon (DOC)
Na	K, Mg, Ca
SO_4	NO_3
Cl	Total nitrogen (unfiltered)
NH_4	Total phosphorus (unfiltered)
Soluble-reactive phosphorus (filtered)	Aluminum (total monomeric) - closed headspace[a]
Aluminum (inorganic monomeric) - closed headspace[a]	Mn
	Fe

[a] Only for EMAP-TIME regions.

3.13 LANDSCAPE STRESSOR INDICATORS

3.13.1 Overall Objectives

- Estimate correlations between ecosystem condition and the landscape stressor(s) which may be affecting it.

- Quantify or apportion the adverse impacts from multiple sources.

3.13.2 Objectives of the Pilot

- Create metrics/indices (or modify existing ones) that reflect a range of conditions from various stressor impacts (i.e., fish stocking, agriculture, silviculture, wastewater, or toxic influence).

- Test ways of filtering and manipulating large amounts of characterization data to produce a quick and flexible approach for obtaining these metrics/indices.

- Develop methods to extrapolate site-specific information into a regional assessment of lake conditions and stressors.

- Map the distribution of relative impacts from various stressors.

- Develop a preliminary model for predicting lake response from landscape variables.

3.13.3 Data Collection and Analysis

Data collection will occur before and during the field season. Available data bases, maps, reports, and remotely sensed information will be used to establish the stressors at the 20 indicator evaluation sites plus the 32 randomly selected lakes that have repeat visits. Only these 52 lakes will be characterized because of the large volume of data expected and the time required to resolve issues of data quality, quantity, and completeness among the data sources.

Land use and point/nonpoint source data are available through the USGS, the Soil Conservation Service (SCS), Census Bureau, Industrial Facility Discharge File (IFD), and various state agencies. Some "ground truthing" may be needed to check the accuracy of these sources. All data will be entered into a Geographic Information System (GIS).

Stressor index development will be an iterative process using spatial and statistical analyses. GIS techniques are needed to classify and display spatial distributions of stressors and evaluate the importance of their proximity to the lakeshore. An ordinal ranking of sites based on the proportions or intensities of major stressors (agriculture, urban/industrial developments) within each watershed could comprise an initial metric. Predictions of relative responses based on stressor data will be compared to the available field response information.

Some statistical analyses must be performed after the field data are analyzed and interpreted. Exploratory techniques may include bivariate plots, cluster analysis, or detrended correspondence analysis.

SECTION 4
DESIGN

4.1 INTRODUCTION AND OBJECTIVES

One of the design objectives for the FY91 Northeast Lakes Pilot is to select a set of lakes from the EMAP-SW grid for pilot field activities. The selection of these lakes must be in concordance with the criteria established for the EMAP probability sampling design (Overton et al., 1990). Analysis of indicators from these lakes will ultimately allow us to evaluate the effectiveness of the baseline grid probability sample design to adequately capture and characterize the diversity of lake resources.

A second design objective is to select approximately 20 to 30 special purpose lakes. These lakes will serve as reference sites and sites of known or estimated impact, chosen in consultation with state and local experts. This combination of sites will be used to help calibrate the sensitivity of the proposed indicators and to evaluate various sampling techniques.

4.2 SELECTION OF GRID LAKES

The general requirements for the overall EMAP monitoring design are that samples should be selected with known probability so that uncertainty in the descriptions of the condition of ecosystems can be calculated. A second requirement is that sampling be spatially representative so that the population descriptions reflect the spatial distribution of the resources of interest. The systematic triangular grid establishes the general framework by which these requirements are met. The search areas specified by the 40 km^2 hexagons centered around each grid point assure spatial representation in the selection of lakes at the first stage (Tier 1 sample) of the lake selection process. Only a subset of this Tier 1 sample of lakes will be visited in the field to make measurements on the condition of lakes (Tier 2 sample). This section describes the steps for the selection of the Tier 1 and Tier 2 samples for the 1991 Northeast Lakes Pilot Survey.

NOTE: In the following sections, unless otherwise noted, the base grid density (a triangular array of approximately 12,600 points fixed across the conterminous United States) will be assumed, and "hexagon" will refer to the 40 km^2 hexagon surrounding each grid point. In accordance with the basic design principles established for EMAP, two fundamental criteria guide lake selection whenever the grid is used. One is that samples are to be selected using probability methods. The second is that the sample maintains spatial representativeness. For lakes, spatial representation means that sample selection reflects the spatial distribution of the population of lakes: where lake density is high, sampling intensity should also be high, and where lake density is lower, sampling intensity should be lower.

Exceptions may occur where it is desirable to focus on selected subpopulations; however, even within areas where these subpopulations can be defined, spatial representation remains an important criterion.

4.2.1 Frame and Tier 1 Sample Selection

The hydrographic layer carried in the USGS produced 1:100,000-scale Digital Line Graph files (DLGs) is used as the frame, representing the population of lakes for the Northeast pilot. These digital files contain the spatial distribution of lakes, including sizes < 1 hectare (ha) as represented on the USGS 1:100,000-scale map series. Our target population consists of lakes in the size class between 1 and 2,000 ha. We used a GIS procedure to extract lakes from these files to produce an inventory for EPA regions 1 and 2 (see Selle, et al., 1991 for details of procedure). Because lake surface area is part of the file, the inventory can be used to create size distributions, to select subpopulations based on size, and to create maps of the distribution of lakes.

The spatial intersection of the grid of 40 km^2 hexagons with the inventory of lakes (each lake uniquely represented as a point) selects the Tier 1 sample of lakes. Random placement of the grid for all resource groups meets the first design criterion (probability based sample selection). The Tier 1 sample contains all lakes between 1 and 2,000 ha whose representative point fell inside a hexagon. Selection of lakes within hexagons associated with the grid points meets the second criterion (spatial representativeness). The Tier 1 sample for the Northeast consists of approximately 1,200 lakes, whose size distribution is plotted with the inventory distribution for comparison in Figure 4-1.

In accordance with the interpenetrating nature of the EMAP probability design, one fourth of the Tier 1 sample is considered for field sampling each year. This set of lakes, termed the Tier 1 Year 1 sample (T1Y1) for the 1991 pilot, contains slightly over 300 lakes (Table 4-1).

4.2.2 Identifying Non-Target Lakes

The lake frame will not be completely accurate due to a combination of mapping errors and changes in the landscape since the time the maps were compiled (some lakes and reservoirs have been drained; others created). It will be necessary to evaluate the changes that have occurred since publication of the maps and to estimate these errors. Those waterbodies identified in the frame as lakes but which in reality do not meet the EMAP-SW definition of a lake are considered non-target lakes.

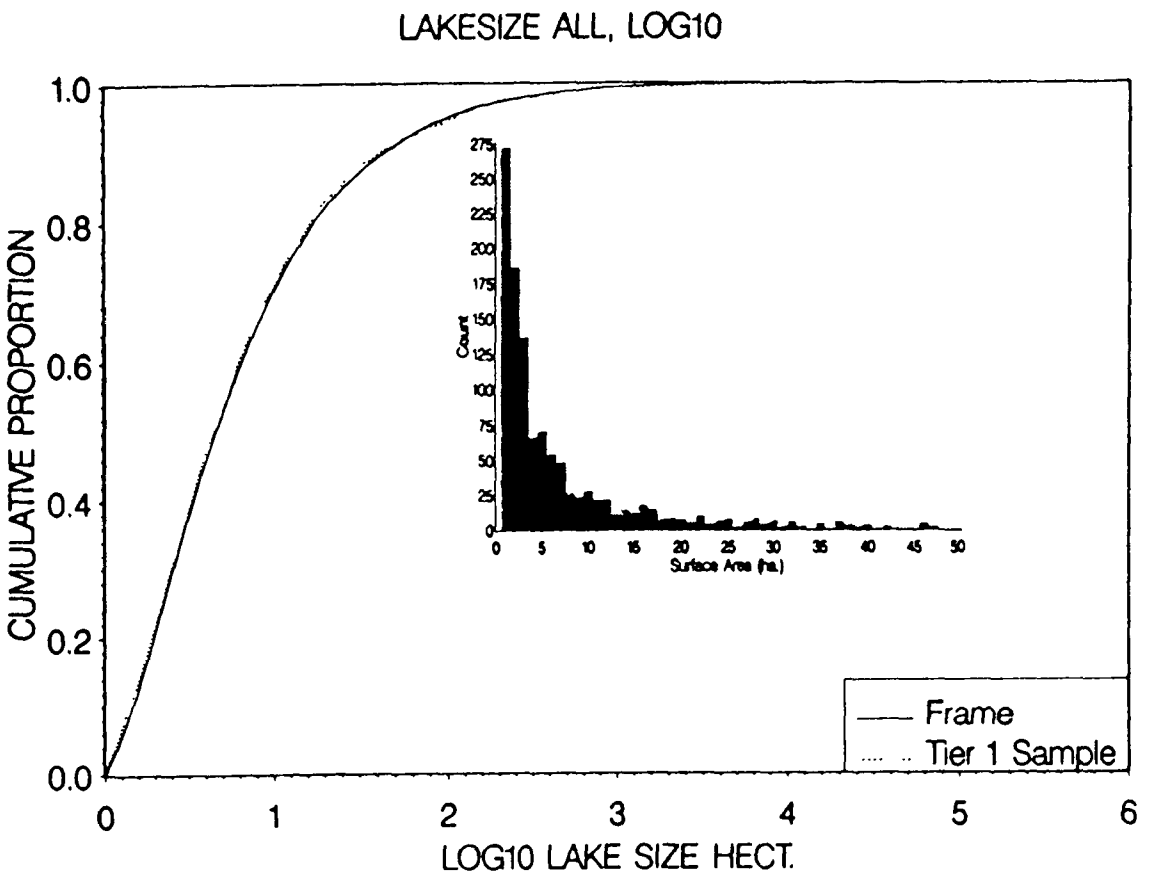

Figure 4-1. Cumulative size distribution for lakes in the Northeast. The insert is a histogram of the size distribution with areas < 50 ha.

TABLE 4-1. NUMBER OF LAKES AND TOTAL AREA PER SIZE STRATA FOR THE NORTHEAST LAKES FRAME, TIER 1 AND TIER 2 SAMPLES.[a]

Size Class	Frame Lakes		Tier 1 Lakes		Tier 2 Lakes		
(Area)	Number	Area	Number	Area	Number	Area	Inclusion Probability
1 - 5	10,791	22,292	662	1,632	16	38	1.95×10^{-3}
5 - 20	5,969	59,207	371	3,651	20	190	3.91×10^{-3}
20 - 500	3,444	276,523	197	16,620	24	1,741	7.42×10^{-3}
500 - 2000	174	162,558	9	7,521	4[b]	2,451[b]	15.63×10^{-3}

[a] (All size and area measures are in hectares. Inclusion probability per strata reported for Tier 2 pilot sample.)

[b] One Tier 2 lake included in this stratum was subsequently found to be under 500 ha.

We evaluated the T1Y1 sample for non-target lakes by examining larger scale maps (7.5-minute topographic and larger scale county maps) and via discussions with local experts. Four categories of non-target lakes were identified in the Northeast: (1) cranberry bog reservoirs; (2) waterbodies identified as portions of larger lakes; (3) wide spots on rivers; and (4) miscellaneous errors. Approximately 15 percent of the T1Y1 sample was considered non-target, with most lakes (45 out of 48) being less than 20 ha in surface area. Identified non-target lakes in the T1Y1 sample were excluded before the Tier 2 selection.

Identifying lakes not represented in the frame will be more difficult and has not been planned as part of the pilot activity. Some methods considered for identifying lakes not represented in the frame include using remote aerial imagery/photography and relying on local experts to provide detailed area knowledge. Both, either in conjunction or separately, can be compared to the lake frame. Our initial sense is that the frame overrepresents the target population in the Northeast, and that there are more non-target lakes than lakes that are missing.

4.2.3 Stratification Strategies

Some discussion has centered on the desirability of stratifying lakes by subpopulations as part of the Tier 1 activity. Part of the discussion was whether a lake classification (other than that based on size) ought to be developed a priori to stratify the Tier 1 sample. Because of the variety of overlapping classifications, it was decided that classification would be best performed as part of the evaluation of results; the lakes can be classified on the basis of the Tier 2 sample and the data summarized according to various subpopulations. After evaluation of the pilot results, we may discover compelling reasons to stratify at Tier 1 in the future.

A second part of the discussion was whether to stratify lakes on the basis of surface area. A non-stratified random sample would select lakes in proportion to their abundance; most of the sampling effort would occur on the smaller lakes. An attractive approach was to allocate equal numbers of samples along a logarithmic or square root transformation of surface area to select more large lakes than would have been selected otherwise. However, allocating samples along a continuous scale requires using variable inclusion probabilities, substantially complicating variance estimation (Overton, personal communication). The issue of whether the advantages of using variable inclusion probabilities outweigh the disadvantages of complicated variance estimation has not been resolved.

In the absence of that resolution, a conservative approach of stratifying on lake area was chosen. An iterative process that varied size classes as strata and sample sizes among strata was used to select samples roughly equally among logarithmic classes, approximating what would have been achieved by using logarithmic or square root transformations. Size classes chosen are: 1 to 5 ha; 5 to 20 ha; 20 to 500 ha; and 500 to 2,000 ha. Table 4-1 summarizes the numbers of lakes in each size class, the stratum inclusion probability, and the Tier 2 sample size.

4.3 TIER 2 SAMPLE SELECTION

The basic design requirements were followed for the selection of lakes for field sampling during the 1991 index period. Because the actual number of these Tier 2 lakes is under continual modification as cost estimates are supplied and refined, we selected 120 Tier 2 lakes with the understanding that we would likely visit no more than 60 of these during the first year of the pilot. We also recognized that it may be necessary to reduce the number of visited lakes further.

The selection of the 120 Tier 2 lakes reflects an iterative process that included several elements:

1. A portion of the sample should be drawn from the grid to initiate EMAP activities; sufficient information is available on some indicators such that EMAP can be implemented for these indicators in the pilot (e.g., water chemistry). To make reasonable statements about condition after the first year, a sample size of about 50 is necessary.

2. There is a need to select a set of lakes subjectively (as opposed to a probability based selection) to assure that there are 20 to 30 lakes that represent both ends of an impairment spectrum (heavily impacted to minimally impacted), or as reference sites of good condition to calibrate sensitivity of indicators.

3. It is necessary to sample a subset of lakes at least twice during the index period to estimate index period variability. It is desirable to sample 20 to 30 lakes during the pilot to estimate this component of variation; in subsequent years it may not be necessary to devote this much sampling effort to estimating index variation.

4. It should be feasible to collect and use some information for purposes of subpopulation development on all Tier 2 lakes, regardless of whether they are field visited or not.

Selecting 120 as a target size for the Tier 2 sample has advantages in that the sample size can be reduced easily in a random way and still meet the criteria for Tier 2 sample selection. For the pilot, the sample is split in half (and added the four largest lakes from the unselected half) to produce the 64 Tier 2 lakes that will be visited in the field. As funding becomes clearer for each sampling year, the number of field visits can be adjusted to a maximum without violating the selection criteria.

4.3.1 Maintaining Spatial Distribution in the Tier 2 Sample

The selection of the Tier 2 sample from the Tier 1 set of lakes was done both to meet the need for a probability sample and to represent the spatial distribution of lakes. Conceptually, the selection process starts by dividing the region of interest into smaller compact clusters, then randomly selecting lakes within each cluster. Cluster size reflects the ratio of the Tier 1 to Tier 2 sample size. Delineating the clusters and selecting lakes within each cluster randomly assures the desirable spatial distribution.

Since the primary function of the delineation of the clusters is to distribute the sampling effort in proportion to the spatial distribution of lakes, the actual dimensions and boundaries need not be precise and are somewhat arbitrarily drawn. However, compactness is a desirable feature; long, thin clusters are undesirable. Also, it is desirable that at least one lake per cluster be selected, but the purpose of defining the clusters is somewhat defeated if more than two or three lakes are selected within each. Thus, the target cluster size is such that two lakes would be selected in each. A final goal was to delineate the clusters in concordance with important geographic features such as physiography or land surface form. Figure 4-2 shows the clusters delineated for the Northeast pilot.

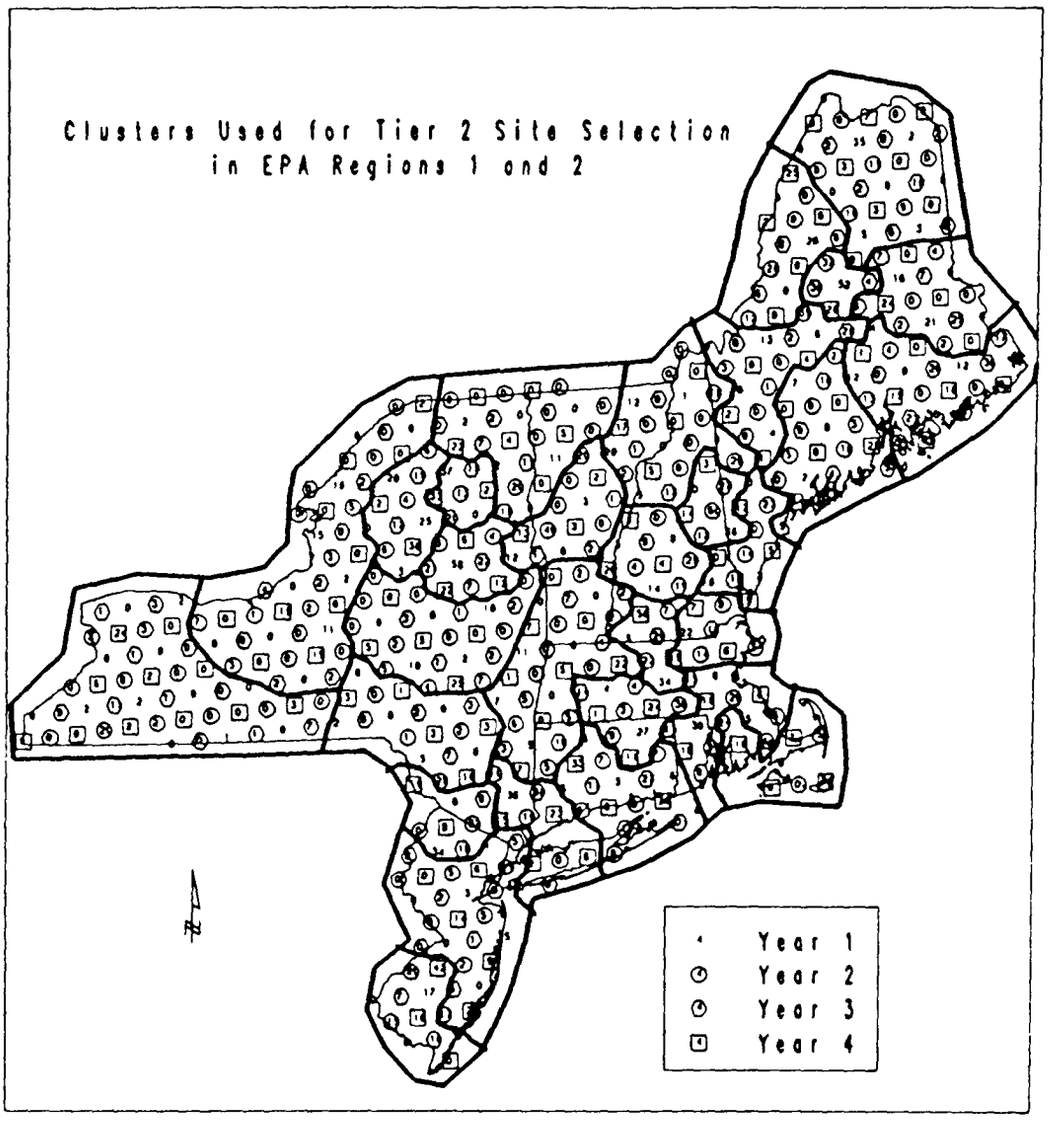

Figure 4-2. Clusters delineated for the EMAP-SW Northeast Lakes Pilot Survey.

4.3.2 Drawing the Tier 2 Sample

The actual selection process included the following steps:

1. Assignment of a weight equal to the square root of the lake surface area to each target Tier 1 lake.

2. Calculation of the total weight to be represented by each cluster as: (2* (total weight in Northeast)/Tier 2 sample size). As noted above, a sample size of 120 was used. Total weight in the Northeast was the sum of the individual weights (calculated as square root of lake surface area) for all Tier 1 lakes.

3. Delineation of the clusters with the above criteria in mind and keeping cluster size as consistent as possible for each year of the four-year cycle. A single cluster represents lakes from all four years; the weight within and among clusters must be approximately equal among years (see Figure 4-2).

4. Selection of the Tier 2 lakes by establishing an array within which random assignment of clusters, then hexagons within clusters, then lakes within hexagons occurred.

5. Within this array, each lake was assigned an arbitrary length proportional to its inclusion probability. Thus lakes > 500 ha (with inclusion probability = 1) have an array length four times that of lakes < 5 ha (with inclusion probability = 0.25).

6. With a random start, move a pointer with an array length of one down the array. The lake identified at each step is selected as a Tier 2 lake.

This procedure was used to select 120 sites for the Tier 2 sample, with four size strata. The sample was then randomly split to produce a sample of 60. Four large lakes were added to produce the final set of 64 lakes proposed for field sampling. Table 4-1 summarizes the lakes chosen in each size class, inclusion probabilities, and other related information.

4.4 INDICATOR EVALUATION STUDY

For a variety of reasons, several indicators were deemed not ready for a demonstration study of their variability among the EMAP grid sites (see Section 3). The major concern centered around fish sampling methods and necessary level of effort. Also of concern was the evaluation of the set of candidate biological indicators for their sensitivity, redundancy, cost, responsiveness, and interpretability. It was estimated that one fish crew

could sample approximately 20 lakes in the 10-week index period; this determined the number of lakes in the indicator pilot. Because sampling methods, effort, and lake condition are largely determined by size, type, complexity, and level of disturbance, it was decided that it was wisest to select 20 lakes rather than draw them from the grid.

The design we selected was based on the variables that best discriminated among several of the indicators. Chemistry (Herlihy, et al., 1991; Landers, et al., 1987), diatoms (Sushil Dixit, personal communication), zooplankton (Richard Stemberger, personal communication), and fish (Cusimano, et al., 1990; Schmidt, 1986; Underhill, 1986) data bases and data summaries were examined and it was concluded that the major gradients were warm-cold, small-large, and reference-impacted. Information on lakes along these gradients were obtained by consulting existing maps, 305b reports, data bases, and state agencies. We first located a set of approximately 150 candidate lakes and then apportioned them as follows:

(1) WARM, LARGE (> 100 ha)--Five lakes in this class arrayed over a gradient of increasing human residential influence from near pristine to an urban, non-industrial setting.

(2) WARM, SMALL (1-20 ha)--Six lakes arrayed over a gradient of agricultural influences and one influenced by toxins, from near pristine to heavily agricultural to urban/industrial.

(3) COLD, LARGE--Five lakes, from relatively pristine to extensively and recently clear cut, especially near the lake.

(4) COLD, SMALL--Four lakes, with little disturbance other than the intensity and timing of fish stocking.

In selecting the lakes we also attempted to cluster them or choose those that were fairly accessible to reduce travel time and maximize sampling time.

SECTION 5
FIELD OPERATIONS

5.1 DESIGN CONSIDERATIONS

Field activities for EMAP-SW will begin in July, 1991 with the lake pilot program in the Northeast. The field operations described here and associated support activities are based on experience gained during the National Surface Water Survey (NSWS) lake chemistry surveys (Morris et al., 1986; Bonoff and Groeger, 1987) and the Biologically Relevant Chemistry (BRC) Survey (Cusimano et al., 1990). The parameters in Table 2-1 (taken from Paulsen, et al., 1991) and the following design characteristics were used for planning and developing the logistics for the Northeast Lakes Pilot.

(1) The index period will be July, August, and early September; a sampling window of approximately ten weeks.

(2) The number of sites sampled will be approximately 64 EMAP-SW grid lakes, 28 TIME lakes, and 32 revisits of EMAP-SW grid lakes. In addition, 20 indicator evaluation sites will be hand selected.

(3) Site selection of EMAP-SW grid and TIME lakes is completely random and does not consider site access.

(4) Lakes range in size from 1 to 2,000 ha.

(5) Small, motorized boats (Zodiacs) will be the primary sampling platform.

(6) Four-wheel drive vehicles will be used for site access and each sampling team will have a second vehicle (e.g., small U-Haul truck) for logistics support.

(7) Field mobile laboratories will not be used, and there will be a minimum of sample preparation in the field.

(8) Samples requiring immediate laboratory analyses will be shipped to the appropriate laboratory by overnight courier.

(9) A field crew will consist of two people for the teams sampling the EMAP-SW grid lakes, and five to eight people for crews sampling the indicator evaluation sites. Efforts at the 20 indicator evaluation sites will be divided among the 5-person fish crew and the 2-person invertebrate crew (Table 5-1).

Based on these requirements, a field crew for the EMAP-SW grid and TIME lakes will be able to sample 1 lake per day, while the indicator evaluation sites will require 2 or more days to sample, depending on the data collection planned. The large indicator evaluation lakes (7,100 ha) will require 3 or more days to sample. Larger lakes (greater than 20 ha) and lakes with difficult access will require additional time and/or staff. A key issue to be addressed in the Northeast Lakes Pilot is what indicators can be adequately characterized given a maximum 2-day sampling period. Invertebrate indicator evaluation at the 20 lakes will be performed by an independent two-person crew and should require one day per lake. A total of 3 field crews will be required to sample all EMAP-SW grid and TIME lakes within the index period. The 20 indicator evaluation lakes will be sampled for all parameters planned for the grid and TIME lakes. The 20 indicator lakes will be used to evaluate the utility of various collection techniques for fish assemblages, fish biomarkers, fish tissue contamination, physical habitat evaluation, and whole lake macrobenthic communities. Table 5-1 provides a schedule for sampling grid and TIME lakes by state, and Table 5-2 provides the division of duties for the fish and invertebrate crews.

TABLE 5-1. DUTIES TO BE DIVIDED BETWEEN THE FISH CREW AND THE INVERTEBRATE CREW

Fish Crew	Invertebrate Crew
Fish Assemblage	Invertebrate Assemblage
Biomarkers	Diatoms
Anomalies	Sediment Toxicity
Tissue Chemistry	Zooplankton
Nutrient Chemistry	Habitat
Trophic State	
Habitat	
Bathymetry	

TABLE 5-2. PLANNED SCHEDULE FOR VISITS TO EMAP GRID AND TIME LAKES BY STATE

State	Number of Lakes	Dates for Sampling
First Sampling Round		
Maine	16	July 8-16
New Hampshire/Vermont	12	July 16-August 23
CT/RI/MA	15	July 23-29
New York	44	July 29-August 19
New Jersey	5	August 19-27
Second Sampling Round		
Maine	10	August 27-September 3
New Jersey/New York	13	September 3-13
CT/RI/MA	6	September 13-16
New Hampshire/Vermont	3	September 16-17

5.2 PROBABILITY LAKE SITE ACTIVITIES

The three two-member field crews will be housed at a motel within 50 miles of the sampling sites. Activities will start each morning by calibrating the instruments and ensuring that all necessary equipment and supplies are loaded into the vehicles (via an equipment checklist). The crews will then depart for the lake.

An additional crew member (field coordinator) will remain at the motel base site; this individual will provide logistics support (picking up equipment and supplies, shipping and tracking samples, transmitting data, contacting landowners, etc.) and will provide a communications link with program management. The field coordinator also serves as a backup sampler.

Figure 5-1a and 5-1b and the following discussion summarize daily activities for the EMAP-TIME sampling crews as detailed in the Field Operations and Training Manual (Tallent-Halsell and Merritt, in preparation).

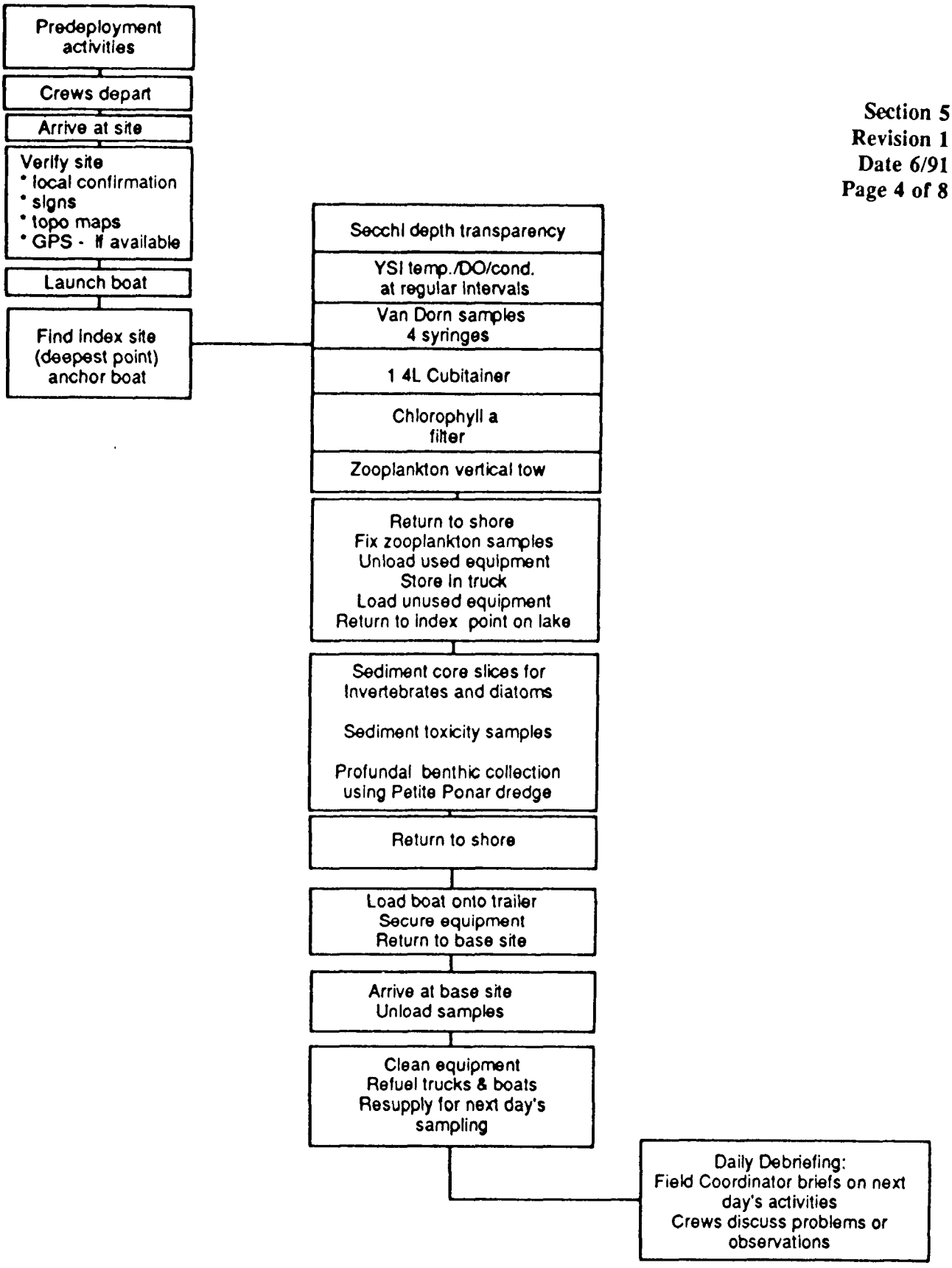

Figure 5-1a. Flow chart of daily activities at EMAP grid and TIME sites.

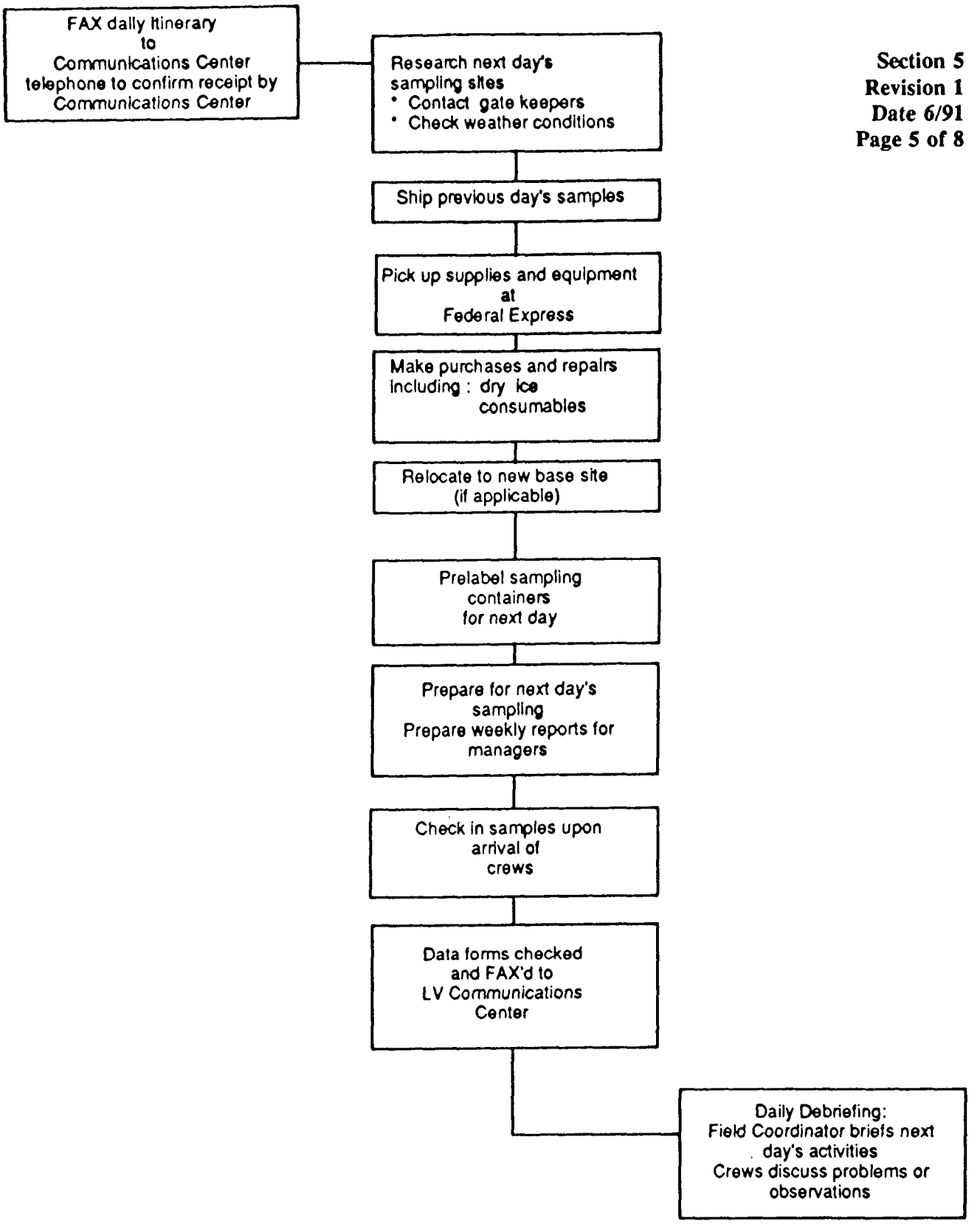

Figure 5-1b. Flow chart of daily activities at EMAP grid and TIME sites.

On arrival at the lake, the field crew will verify that they are at the appropriate lake. Lake verification will be based on landscape features and topographic maps, and/or GPS information, if coverage is available at that time. An inventory of all equipment and supplies will be performed, the water sampling and zooplankton collection equipment will be loaded into the boat, and the boat will be launched.

The boat crew will first conduct a survey to determine the deepest part of the lake using sonar. This activity is followed by anchoring at the index site (the deepest part of the lake) and collecting water chemistry samples, chlorophyll a, Secchi disc transparency, DO and temperature profiles, and zooplankton samples. All samples are preserved (when appropriate), labeled, and packed for return to the base site, and the boat is returned to shore. The boat is then re-outfitted for collection of sediment samples. Profundal benthic invertebrates will be collected using a petite PONAR dredge; sediment core slices from the surface and bottom of benthic core samples, and sediment for toxicity tests (PONAR) are collected at the index site. All samples are checked for completeness against a checklist and then packed for return to the base site.

At the motel, the field coordinator will debrief the sampling crews and check the data forms, sample labels, and the condition of the samples. Selected data forms will be transmitted via facsimile to the Las Vegas Communications Center for data entry after they have been reviewed by the field coordinator. The sampling crews and the field coordinator will clean and prepare equipment and supplies for the next day.

Water chemistry and chl a samples will be shipped to the analytical laboratory the following morning, while sediment toxicity samples may be held for shipment for up to one week. The preserved benthic invertebrate, zooplankton, and sediment diatom samples will be stored for later shipment. Table 5-3 summarizes the number of samples and measurements to be taken at EMAP-SW grid and TIME lakes.

TABLE 5-3. NUMBER AND TYPE OF SAMPLES TO BE COLLECTED AT EACH EMAP-SW GRID AND TIME SITE

Indicator	Number	Type of Container
Zooplankton	1	125-milliter Nalgene
Sediment Core	1 top, 1 bottom	2 1-quart Ziplocs
Sediment Toxicity	1 3-L sample	2 1-gallon Ziplocs
Ponar Dredge	3	500-milliter Nalgene
Water Chemistry	1	4-liter Cubitainer
Water Chemistry	4	60-milliter syringe
Chlorophyll a	1	GFF filter in foil

On the next day, the field crews will travel to a new set of lakes and the field coordinator will move to a new motel base site, if a move is logistically necessary. The field coordinator will FAX data and forms to the Communications Center each day, will take the samples to the overnight courier, and pick up additional supplies and equipment. The specific location of the courier will be predetermined during reconnaissance and verified through daily communications with program management.

5.3 INDICATOR EVALUATION LAKE SITE ACTIVITIES

The 20 lakes will be sampled by four different crews. Two bird crews (via a cooperative agreement with the University of Maine) will sample all 20 lakes twice in June. A macroinvertebrate crew will collect benthic organisms, sediments, zooplankton, and physical habitat data. The fish crew will take fish, biomarker, tissue residue, nutrient chemistry, and physical habitat samples.

TABLE 5-4. SAMPLES COLLECTED AT THE 20 INDICATOR EVALUATION LAKES

Sample Type	No. Lakes	Treatment
Fish Assemblage	20	Tally
Liver, Gill, Blood	4	Foil in Nitrogen-Dry Shippers, dry ice
Anomalies	20	Tally
Tissue Chemistry	4	Foil; 5 whole, 5 filet, dry ice
Invertebrate Assemblage	20	500-mL Nalgene, formalin
Diatoms	20	4°C, Ziplocs
Zooplankton	20	CO_2, formalin, 125-mL wide-mouth Nalgene
Nutrient Chemistry	20	125 mL Nalgene, H_2SO_4
Chlorophyll a	20	Dry ice, foil, Ziplocs
Sediment Toxicity	20	4°C, Ziplocs
Physical Habitat	20	2 Field sheets per crew

Birds and their habitats will be sampled in early morning by observations at 10 to 20 (depending on lake size and complexity) transect points along the lake shore. Communications and data entry and storage will be coordinated by the University of Maine. The benthos crew will first sample physical habitat to determine major habitat types and sites in which to sample benthos. Nearshore sampling will be followed by sediment coring and sediment dredging for profundal benthos and sediment toxicity tests.

The fish crew will also sample physical habitat to determine fish collection sites for the various types of gear. Passive gear will be set overnight and active fish sampling will occur at night. The following day, fish tissue and biomarker samples will be taken and preserved. Before leaving the lake, water quality and zooplankton will be sampled and preserved.

SECTION 6
QUALITY ASSURANCE PROGRAM

For the Northeast Lakes Pilot Survey and TIME project, quality assurance and quality control (QA/QC) are an integral part of all activities associated with the collection, measurement, and management of environmental data and information. The major purpose of a formalized QA program is to ensure data are of adequate quality to provide information which can be used with confidence to satisfy the research objectives of the project. For the pilot study, information is required to determine the adequacy of the proposed probability-based sampling design. Information is also required to evaluate the feasibility of several different types of ecological indicators being considered for use in large-scale monitoring efforts of lakes. For the TIME project, the research objectives relate primarily to determining the status and subsequent regional trends in lake chemistry relative to acidification.

Major objectives of the QA program developed for the Northeast Lakes Pilot Survey and TIME project are:

- Implementing appropriate QC and quality assessment measures for each ecological indicator, providing measurement data of known quality to adequately satisfy the research objectives for that indicator.

- Obtaining estimates of various sources of error (sampling and measurement) associated with the sampling design and with individual ecological indicators.

This information is required to develop appropriate data quality requirements for subsequent studies, considering the quality required for data interpretation and limitations to quality posed by available methodologies. For individual indicators, the allocation of QA/QC efforts can be optimized based on this information. Finally, the sampling design can be refined for future efforts with this information, in terms of the required number of lakes, and the temporal and spatial allocation of sampling effort.

6.1 DATA QUALITY REQUIREMENTS

Data quality requirements necessary to provide information that can be used with confidence to satisfy the research objectives of the pilot study are established for five different elements (following Smith, et al., 1988). Precision and bias requirements relate to the tolerable amount of random and systematic errors, respectively. Precision and bias are determined through the use of replicate sampling and analysis, use of PE samples of known composition, and, in the case of taxonomic identification, through confirmatory identifications by independent experts. Completeness requirements stipulate the minimum

amount of valid data necessary to confidently interpret the information relative to the research objectives. A minimum number of lakes must be sampled to provide population estimates which have acceptable confidence limits. For the indicator evaluation study, data must be collected from a variety of lake types and disturbance regimes to properly evaluate the sensitivity of a particular ecological indicator. Comparability requirements establish the criteria that allow information collected by different sampling teams and measured by different laboratories to be confidently combined before interpretation. Consistent use of standard procedures for data acquisition and subsequent reporting are used to ensure comparability in data and information generated during the pilot survey. Documentation of methods, precision and bias, and other pertinent information are required to determine comparability of the pilot survey data with other data sets. Requirements for representativeness are established to ensure that the information and interpretative conclusions that result from a study provide accurate inferences to the true state of nature. The first requirement for representativeness is a sampling design to provide statistically unbiased (and thus representative) population estimates. Criteria are also established for obtaining ecological data from lakes which are characteristic of conditions during the specified index period. In some cases (e.g., water chemistry), a single sample is sufficient; in others (e.g., fish assemblages), several different locations on an individual lake must be visited to obtain a single sample that adequately characterizes the extant assemblage composition and relative abundance.

6.2 MAJOR ELEMENTS OF THE QA/QC PROGRAM

Major elements of the QA program are presented in Table 6-1, and are generally applicable to all types of activities related to data acquisition and management. Management policies and philosophies related to the overall QA program for EMAP will be documented in a QA program plan. Policies and guidelines for QA and QC which pertain specifically to Surface Waters activities will be documented in an integrated QA project plan (QAPjP). The QAPjP will describe the policies, procedures, and acceptance criteria to define, monitor, and evaluate data quality to ensure it meets or exceeds established requirements for the program. Research objectives and the proposed plan for the pilot survey are presented in this implementation plan. Standard procedures associated with field operations are described in the field operations manual (Tallent-Halsell and Merritt, in preparation). Analytical methods are summarized in the methods manual (Klemm et al., in preparation). The strategy and procedures used to manage data and associated information is presented in the information management plan (McGue, in preparation).

TABLE 6-1. ELEMENTS OF THE QUALITY ASSURANCE PROGRAM, NORTHEAST LAKES PILOT STUDY AND TIME PROJECT

Program Element	Mode of Implementation
Document plans, procedures, methods, and data quality requirements.	Preparation of implementation plan, field operation manual, methods manual, QA project plan, and information management plan.
Responsibility and Accountability	Define project organizational structure and responsibilities.
Ensure appropriate technical skills and competency of project participants.	Training program for field personnel prior to initiation of sampling operations; Laboratory performance evaluation prior to any analyses.
Correct and consistent implementation of required procedures.	Site visits and auditing activities, with prompt implementation of required corrective actions.
Maintain data acquisition systems within required data quality criteria.	Define preventative maintenance requirements for equipment and instrumentation. Specify calibration procedures and frequency. Implement appropriate quality control measures at critical points of system. Monitor performance as data are acquired against acceptance requirements and correct problems promptly.
Ensure recorded data and information are accurate and of acceptable quality.	Specify reporting format, units, and range of acceptable values (or codes). Review recorded data at point of collection and after entry into computerized data base. Verify accuracy and acceptability of information using internal consistency checks and quality control information; validate data for intended use by exploratory statistical analyses.
Determine and report achieved quality of data.	Assessment of quality against requirements for precision, bias, completeness, comparability, and representativeness, using estimates of variance components, performance evaluation data, quality control information, and results of verification and validation analyses.

The development and implementation of the QA program for the pilot study is the responsibility of the Surface Waters QA Officer. Those aspects of the overall QA program which are of direct relevance to the TIME project are directed by a designated QA representative for the project. Project organization and responsibilities are documented in the QAPjP.

Training programs for field personnel are conducted before sampling activities commence. Training ensures consistent implementation of the required procedures and attainment by each person of a desired level of technical competency. Formal training programs for laboratory personnel are not required; laboratories providing analytical support are evaluated before analytical activities to ensure they can conduct the appropriate analyses and produce data of the required quality. Laboratory evaluations are conducted using blind PE samples and by site visits.

Site visits of field operations and laboratories will be conducted by experienced technical and QA personnel. Such visits ensure that documented methods are being implemented correctly and consistently.

For each indicator, critical points in the information acquisition process are identified and subjected to internal QC procedures and/or measurements. Statistical process control methods (e.g., control charts) are utilized where possible to monitor the performance of the acquisition system. These methods provide rapid feedback on the performance of the system to allow for prompt corrective action, ensuring data quality remains within established acceptance criteria during collection and measurement. Specific QC requirements and procedures to be used for each indicator are described in the QAPjP.

Standardized procedures will be developed for the review of data during recording, and during subsequent entry into a computerized data base. Standardized recording forms and sample labels are used to maintain consistency in data recording within the pilot survey. Review procedures include an independent review of forms at the point of measurement, and comparison of computerized entries against the original recording form.

Data are verified to confirm that information associated with an individual sample or measurement is accurate with respect to what was initially recorded, and that all QC acceptance requirements have been met. Verification is conducted using automated review procedures, such as range checks, frequency distribution of coded variables and other internal consistency checks (e.g., calculated chemical ion balance checks, summation of relative abundance estimates, and absence of expected taxonomic groups), and review of associated QC information. Verified data are subjected to validation procedures to identify data values which are potentially unrepresentative because of anomalous conditions at the time of sampling.

Various univariate and multivariate statistical procedures are used on the verified data to identify outlying observations which are subjected to additional review.

Assessments of data quality against the established data quality requirements are conducted to determine the overall performance of the QA program, to identify potential limitations to use and interpretation of the data, and to provide information for other data users to make determinations regarding the usability of the data for other purposes. Such assessments are a part of project interpretative reports, as well as other products (e.g., accompanying data bases).

Finally, scientific peer reviews of the activities (and products) of the pilot survey are conducted to help guarantee that the information acquired for the pilot survey and the TIME project are technically sound and suitable to meet the objectives of the project.

6.3 ASSESSMENT OF DATA QUALITY

The success of the QC measures implemented to maintain data quality within acceptable bounds is evaluated a posteriori in several ways. Precision and bias associated with important components of the sampling and measurement processes of individual indicators are evaluated using results from carefully designed replicate sampling and PE studies. Results of verification and validation procedures provide information on the amount of acceptable data of the type required to satisfy the requirements established for completeness. Information on precision, bias, and completeness are used to determine the comparability of data acquired during the study. This information is important for those ecological indicators that must use additional information acquired as part of measurement programs for other indicators (e.g., the sediment diatom assemblage indicator requires water chemistry data to allow historical inferences to be made regarding trends in water quality characteristics). After acceptable comparability is determined, overall representativeness of the information in satisfying the research objectives can be ascertained.

6.4 ESTIMATES OF COMPONENTS OF INDEX PERIOD VARIATION

Certain components of variation that relate to the sampling design and sampling strategy within a single index period (Table 6-2) are estimated using temporal (and in some cases spatial) sample replication schemes. Temporal variation of conditions within the index period are estimated by sampling 32 of the probability sample lakes twice during the course of the pilot survey. Spatial variability that exists within an individual lake during a single sampling event will be estimated only for the sediment toxicity indicator. At two lakes selected for the indicator evaluation pilot study (representing a lake suspected of having contaminated sediments and one known to be free of contamination), sediment samples are collected from three sites (a profundal site and two near-shore sites). The results of sediment

bioassays from each sampling location will be used to determine if spatial variability in acute toxicity is greater than the variability resulting from single profundal samples collected from a number of lakes.

Temporal and spatial variability during an index period are potentially confounded by variability or bias resulting from different sampling crews visiting a site and collecting a sample, or from the same crew visiting a site more than once, and introducing bias due to increased experience, or increased variability due to a lack of attention to standard operating procedures

TABLE 6-2. SOURCES OF VARIATION OF INTEREST, EMAP-SW NORTHEAST LAKES PILOT SURVEY

Variance Component	Description	Method of Evaluation
$\sigma^2_{temporal}$	Variance resulting from temporal differences in an index sample from a single lake within a single index period.	Repeat visits to 32 lakes during the index period.
$\sigma^2_{spatial}$	Variance resulting from spatial differences within a lake for a single sampling event.	Collection of additional samples from several locations at individual lake.
σ^2_{team}	Variance resulting from different crews collecting data from a single lake	Independent sampling of individual lakes by two teams within a 2-day period.
σ^2_{meas}	Variance resulting from the collection, handling, and analysis of samples.	Replicate sampling at a single site at individual lakes; Use of evaluation samples of known composition which are introduced in the field or at the laboratory; Replicate analyses of individual samples.

because of a crew's perceived familiarity with them. Such crew effects could severely impair the interpretation of regional patterns or trends. It is not feasible to factor out crew effects by assigning lakes to each crew at random (regardless of location), or to sample the lakes at random within an index period. Thus, there is a potential for all lakes within a subpopulation of interest to be sampled by the same crew. It is also likely that, for a given subpopulation, some lakes will be sampled early (when crews are inexperienced), while others will be sampled later (when crews are experienced).

To assess the potential impact of "team effects", a subset of lakes will be visited and sampled on successive days by two different crews. The collection of these "team duplicate" samples will be spaced over the duration of the index period to investigate changes in performance due to experience. Lakes selected for team duplicate sampling will have to be in close proximity to each other. To the extent possible, candidate lakes for team duplicate sampling should include those selected for revisits during the index period.

One important contribution to σ^2_{meas} (Table 6-2) will not be determined during the pilot survey. Because only one laboratory will be utilized for analytical support, variability due to random and systematic errors among laboratories cannot be estimated. The total variance associated with the replicate lake samples will include an among-batch contribution from a single laboratory.

6.5 DISCUSSION AND SUMMARY

Many facets of the QA program implemented for the pilot study are themselves "pilot" in nature. For a number of the indicators being used and evaluated, formalized QA/QC practices have not been developed, or existing practices are not appropriate for the proposed sampling strategy of EMAP-SW (i.e., synoptic sampling at a large number of lakes using an integrated sampling program to concurrently collect a diversity of data for several indicators). Appropriate criteria for defining the "quality" of information associated with various ecological indicators is currently lacking.

The various aspects of the QA program will be reviewed following the completion of the pilot survey. Realistic data quality requirements will be developed for the various indicators and their associated measurements. Replicate sampling and PE studies, as well as QC measures, will be optimized to provide the necessary information with a minimal number of measurements.

Refinement of the QA program will be accomplished through a team effort of program management, scientists responsible for the design, collection, and subsequent interpretation of ecological indicators, and QA personnel. Management must be committed to providing adequate resources to both successfully complete projects and to provide for the documentation of the quality of acquired information. The research scientists should use QA as a tool to facilitate the interpretation of status and trends in condition, using information from their respective indicators. Quality assurance personnel have a responsibility to develop a QA/QC program that provides information on data quality of maximum value to prospective users. This information must be collected with minimal impedance to the research activities or associated operations.

SECTION 7
INFORMATION MANAGEMENT

7.1 INTRODUCTION

EMAP-SW will be collecting a large volume of data during the FY91 Northeast Lakes Pilot Survey. More than 50,000 data points will be generated from the data collection activities at approximately 100 lakes; this estimate does not include the revisited lake sites. The ability of EMAP-SW to manage and disseminate this amount of information will have a major influence on the success of the program. Development of an adequate Information Management System (IMS) is, therefore, as important to the success of EMAP-SW as is the collection of the data. A fully automated system for the FY91 field activities ensure that data are properly collected and tracked in a timely manner for analysis.

7.2 OPERATIONAL COMPONENTS OF THE IMS FOR EMAP-SW FY91 PILOT SURVEY

The system designed to date was intended to provide the EMAP-SW Resource Group with the optimum resources and automated systems for supporting information management (IM) activities. Only critical systems that will ensure the success of the data collection activities will be implemented for the pilot program. The Surface Waters Information Center (SWIC) will be located at Lockheed Engineering & Sciences Company, Las Vegas, Nevada (LESC-LV). The following describes the components that will be available for the FY91 field activities. It does not include data analysis activities or final reporting.

- Frame Development Data Base (Tier 1 sites) - Contains information on all Tier 1 lakes (e.g., name, contacts, etc.). This data base has also been used for lake selection (Tier 2 sites). Data entry screen interfaces have been developed in the Statistical Analysis System (SAS) on the Virtual Address Extension (VAX).

- Lake Access Data Base - Contains all information on the Tier 2 and Tier 3 (TIME and reference) lakes. Data entry screens have been developed for this data base and can also be used to aid in obtaining information for lake access.

- Sample Tracking System - Sample tracking will be fully automated with the use of bar code readers. This will facilitate the identification and tracking of all samples collected in the field. The system will check that all appropriate sample containers go out to the field and that all samples were collected. The sample tracking data system will also link sample identification information with all pertinent site information. This information will then be transferred to a floppy disk and shipped by Federal Express within 48 hours along with the

original field forms. This information can also be output and sent via FAX to the SWIC.

- Portable data recorder (PDR) - This system will only be tested with one field crew at the 20 special interest lakes. Data entry screens will be developed and programs will be written for the Global Positioning System (GPS). This will allow for the direct linkage of the sonar reading with the latitude and longitude for all locations. If time permits, data entry screens for fish identification will also be written. Until these systems have been fully tested, field forms will also be used. Data stored will be transferred to a laptop at the hotel nightly and then to a floppy for shipment with the field forms and sample tracking information.

- Logistic Information System - A predeployment GIS data base will be established to help prepare for field activity and effectively monitor and coordinate field operations. The predeployment data base will provide logistical support for sampling teams by identifying locations of ancillary facilities and information for gaining access to sampling sites. This will include information and location of hotels, Federal Express facilities, dry ice locations, hospitals, boat repair facilities, post offices, and other pertinent facilities. At present, the information will be stored on the VAX in a SAS data base. Accessing this data will have to be done by someone knowledgeable of SAS, as query screens will not be developed. However, if GIS support is available, this system will be implemented and maintained in ARC/INFO, with user friendly interfaces. This will allow for the display of spatial data associated with a given site (i.e., the field coordinator could monitor sampling progress using simple mapping techniques).

- Data entry screens - Entry screens for all field forms will be developed. Some entry screens will be implemented in C programming language for the field laptops and PDRs; all others will be developed in SAS for data entry at the SWIC. Whenever possible, QA/QC checks will be embedded into the data entry screens to ensure validity. Double entry will also be used to QA the data. Data entry screens will not be developed for the analytical laboratories. Samples will be sent to the analytical laboratories with the necessary information and results will be sent back in a specified format.

- GPS - There are a several areas in which the GPS units will help us. They are as follows: developing bathymetry maps, developing indexes of variability for the morphology of the lakes, determining residence time, and as an aid in the development of the physical habitat and characterization of the lakes. They will also be used to determine if the field crews are at the correct site, and to

determine the location of sample sites (grabs, etc.) so that site can be found upon return visits. The locational data collected by the field crews will be stored in non-volatile memory and then downloaded to a laptop that night back at the hotel. QA programs will be developed to ensure that the locations were not recorded twice. Programs will also be developed to link this information with the proper sample information, and the lake depth (taken by sonar). Customized screens will be developed for the polyrecorders while in the field. A base unit will be located at a base site supported and operated by Region 1. This allows for the post-processing of the data using differential calculations to provide better accuracy of the locational information recorded.

- Field forms will be designed and generated that will be used as backup for electronically entered data. However, some data will still be recorded solely on hard copy forms in the field. The forms will be printed on waterproof paper to facilitate field data entry during inclement conditions. Backups will be made at the hotel (using the FAX machines as copiers).

- QA/QC reports will be generated during data entry for verification. Questionable data will be flagged, and added to a report which will be given to a qualified person for validation. Some of this will be automated; however, some will be done manually.

- Personnel Information System - This information will be available on hard copies only. When time permits, it will be electronically entered and stored in a data base in SAS on the VAX.

- Sample Labels - Labels will be preprinted and bar coded for sample tracking.

- GIS - The integration with these activities are unknown at this point.

SECTION 8
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15. SUPPLEMENTARY NOTES

16. ABSTRACT

This document outlines the proposed implementation plan for the Environmental Monitoring and Assessment Program's Surface Waters Northeast Pilot Lake Survey, to be conducted in July through September, 1991. The pilot survey will evaluate not only the utility of the indicators selected thus far for the Surface Waters component, but will provide an evaluation of the methods that have been identified for collection and analysis of samples.

This implementation plan is not intended to be a step by step delineation of field activities planned for the pilot; for more detailed discussion of concept, approach, and issues, please refer to either the Surface Waters Research Plan (Paulsen et al., 1991) or the respective subject plans (i.e., the quality assurance project plan, the field operations manual, the information management plan). This plan outlines the objectives of the field pilot activities and the questions which we expect to answer as a result of these activities. In addition, the plan contains a description of the indicators, the measurement variables included in each indicator the design rationale, and details including site selection criteria and a list of selected sites. Very brief descriptions of quality assurance, logistical considerations, and the information management approach are also presented.

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